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ABSTRACT:

Sediment core samples and grab samples were collected from selected sites in the Clinch River and Watts Bar Reservoir. These samples were analyzed for 137 Cesium activity (pCi/g) and several physical parameters (critical shear stress, organic matter content, cation exchange capacity, dry density, percent moisture content, settling velocity and porosity). Data were then used for model calibration. Types of sediment were classified as: soft mud; cohesive mud; sandy mud; sand/gravel; and, submerged soil.

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SUMMARY REPORT OF THE NUMERICAL MODELING OF SEDIMENT TRANSPORT FIELD COLLECTION TASK OR SOME SIMILAR SUCH TITLE

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1.0 INTRODUCTION

1.1 OBJECTIVES AND SCOPE

Activities at the Oak Ridge Reservation since the 1940s have resulted in the release of contaminants into local aquatic environments. Most contaminants of concern are chemically and biologically reactive, and become associated with particles in freshwater systems. The purpose of the Numerical Modeling of Sediment Transport (NMST) task of the Clinch River Environmental Restoration Program (CRERP) was to help characterize the nature and extent of contamination in sediment by modeling how sediments and their associated contaminants move into and through the Clinch River/Watts Bar Reservoir (CR/WBR) system. Sediment core and surface grab samples were collected from selected sites in the river/reservoir system, and analyzed for ^{137}Cs activity and several physical parameters to provide data for model calibration. This document describes the sample collection strategy for the NMST task, how the samples were collected, processed, and analyzed, and a brief description of the data that resulted from those analyses. A detailed description of the models and their output is beyond the scope of this report.

1.2 RESPONSIBLE ORGANIZATIONS

The NMST task was conducted as part of an Interagency Agreement between Oak Ridge National Laboratory (ORNL) and the Tennessee Valley Authority (TVA). The modeling approach used three separate one-dimensional water and sediment transport models implemented independently by ORNL (HEC-6), TVA (CHARIMA), and the Pacific Northwest Laboratory (TODAM). The groups using each of the models collaborated extensively on model development, model input estimation, calibration and corroboration, and scenario selection.

The field collection task for the project was conducted by teams composed of personnel from the TVA and CRERP. The CRERP was responsible for overseeing the collection, processing, and analysis of the samples. Members of the TVA were responsible for assisting CRERP personnel in the collection of sediment samples, maintaining chain-of-custody of all samples, with the exception of those samples returned to the custody of CRERP personnel for ^{137}Cs analysis at the Environmental Sciences Division Radiochemical Analysis Laboratory (ESD RAL), and for delivery of samples to analytical laboratories.

2.0 METHODOLOGY

2.1 SAMPLE COLLECTION AND PROCESSING

A total of 54 sediment cores from 16 sites, and 31 surface grab samples at five transects were collected for this task. All samples were collected between April 19, and May 13, 1993.

2.1.1 Core Samples

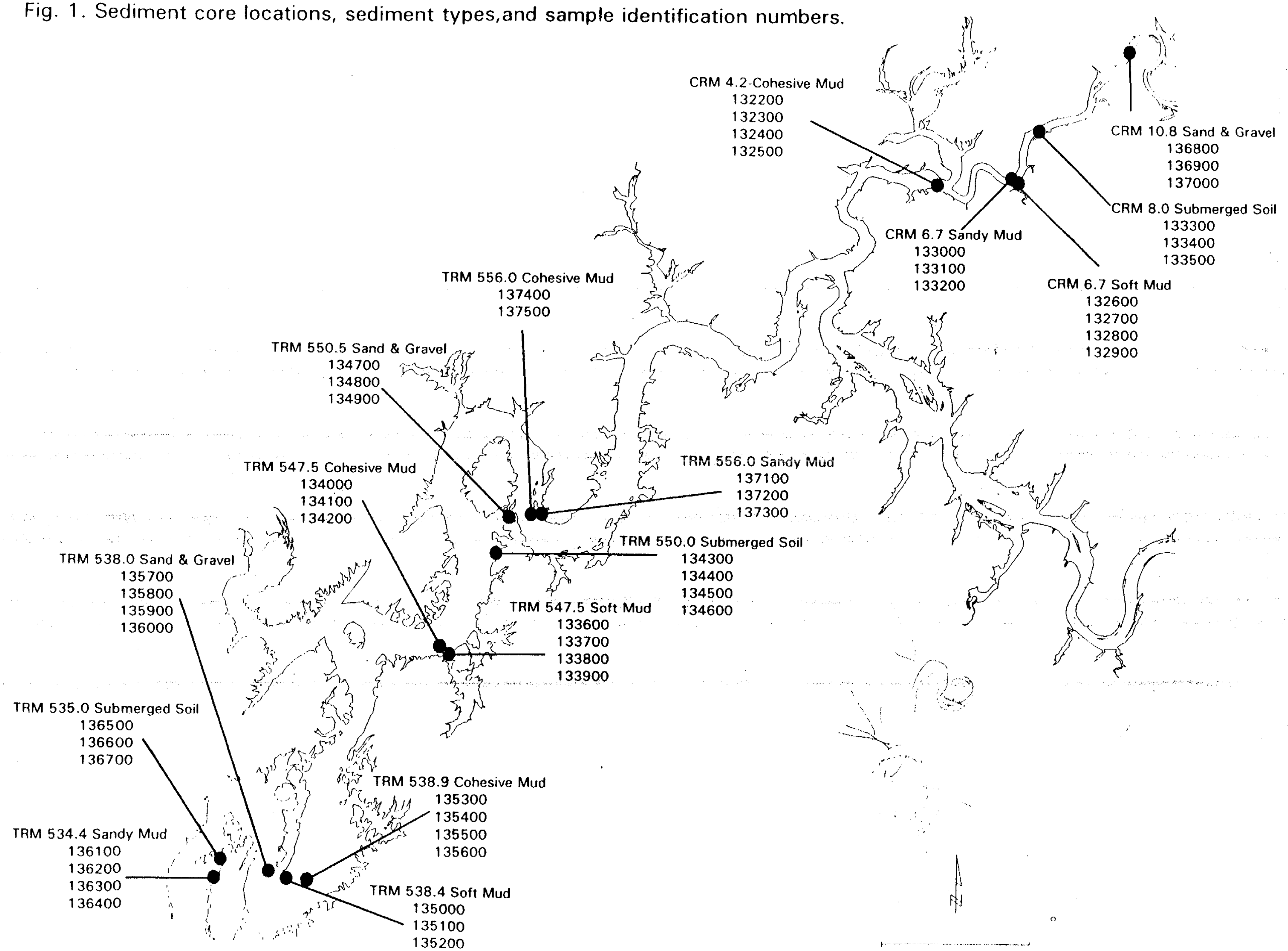
Watts Bar Reservoir is defined by the TVA as that part of the Clinch River system from Melton and mercury in the Clinch River and Watts Bar Reservoir, Olsen et al. (1992) identified five different sediment types in the Watts Bar Reservoir. Those sediment types are described as soft mud, cohesive mud, sandy mud, sand and gravel, and submerged soil. For this project, sediment core samples were collected from three different sites in the Watts Bar Reservoir representing each sediment type (e.g. three soft mud sites, three cohesive mud sites, etc.). Specific areas for sampling were based on the availability and distribution of the sediment types. Sediment cores were collected using a Wildco KB Core Sampler. Depending on the analysis to be performed, the sampling device was equipped with either a 2 or 3-inch diameter core tube fitted with cellulose acetate butyrate tube liners. One site for each sediment type was selected in the Clinch River arm of Watts Bar Reservoir, between Clinch River miles (CRM) 4.2 and 10.8; one site was selected from mid-reservoir, between Tennessee River miles (TRM) 547.5 and 556; and the third site representing each sediment type was selected in lower Watts Bar, between TRM 535 and 538. Sample locations are shown in figure 1. Sites were chosen initially using Olsen's map of sediment types. A sediment grab sample was taken at each site and visually inspected to determine if the sediment was the type indicated by the map. If the sediment was the correct type, that site was determined to be appropriate, and cores samples were collected. If the visual inspection indicated that the sediment was not the correct type, the process was repeated at nearby locations until appropriate sediment types were found. At two of the sites representing each sediment type, three cores were collected and split for analysis to determine dry density, organic matter content, cation exchange capacity, particle size distribution, settling velocity, moisture content, porosity, ^{137}Cs activity, and critical shear stress. At the third site representing each sediment type, a fourth, additional core was collected solely for particle size analysis. At one site (TRM 556) two cores were collected and analyzed only for ^{137}Cs activity.

Sample collection locations were recorded using a Global Positioning System (GPS). GPS is a technology that calculates positions by triangulating on three or more orbiting satellites. By post-processing GPS data collected by the field receiver, locations accurate to less than one meter are obtained.

One sediment core collected from each site was submitted to the Soils Laboratory at the University of California, Davis, for critical shear stress analysis. The samples were shipped intact in the core tubes to maintain the integrity of the sediment. To facilitate shipping, the core tubes were cut to 12 inches in length, measured from the top of the sediment. The excess water was removed from inside the tube, and both ends capped and sealed to prevent moisture loss. If samples were less than 12 inches long, the core tubes were cut to the length of the sample. In order to minimize chemical and biological activity, the samples were stored and shipped as close to 4°C as possible until analyzed. Approximately one gallon of lake water taken from the sample site near the sediment/water interface was required for the critical shear stress analysis. The water sample was collected prior to the core samples in order to avoid obtaining a disturbed water sample. Water samples were stored in darkness to minimize algae growth.

The second core from each site was transferred by CRERP staff to the ESD RAL for ^{137}Cs analysis. Two inch diameter cores were used for this analysis. Core samples were partitioned at ESD into sections 6 cm in length, homogenized, and placed in 90 cm^3 aluminum cans for analysis.

Fig. 1. Sediment core locations, sediment types,and sample identification numbers.



The third core from each site was submitted in its core sleeve to Singleton Laboratory, Louisville, TN, for analysis for dry density, cation exchange capacity, organic matter content, moisture content, porosity, particle size determination, and settling velocity. To facilitate handling and delivery, the excess water was siphoned from inside the tube, the sleeve cut to the length of the sample, and both ends capped and sealed to prevent moisture loss. Core samples were partitioned into 6 cm sections in the laboratory prior to analysis.

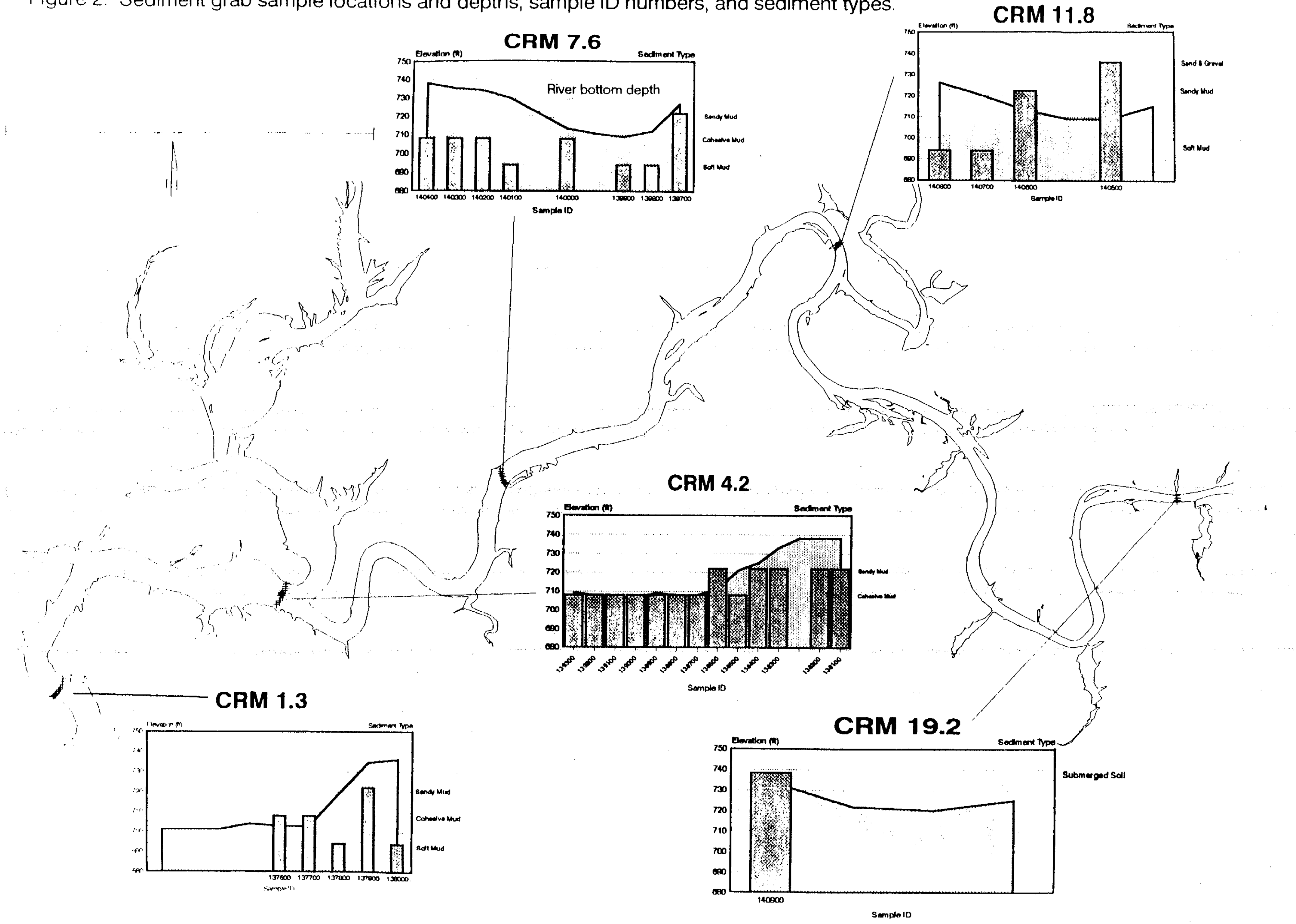
To obtain added resolution for particle size analysis, a fourth, additional core taken from one site representing each sediment type (5 cores total) was partitioned into 2 cm sections, and submitted for analysis. Excess water was removed from cores as described above.

Due to the density and composition of the sediment, the soft mud and cohesive mud samples produced the longest cores, and the submerged soil, and sand/gravel samples were the shortest. The total number of core sections analyzed from each site was a function of the core length, and varied from site to site. Samples were selected for analysis based on the importance of the data and the budgetary constraints of the project. Analyses for particle size determination, organic matter content, and dry density were performed on all sections of one core collected from each site. Only one critical shear stress sample (top 3.2 inches of the core), and one cation exchange capacity sample (6-12 cm depth, if available), was submitted per site. Settling velocity was determined only for the 0-6 and 12-18cm sections; moisture content and porosity were determined for only the 0-6, 12-18, and 42-48 cm core sections. For cores with too few sections to follow this pattern, analyses were performed on sections higher in the core, or if insufficient sample was obtained, not at all.

2.1.2 SEDIMENT GRAB SAMPLES

Sediment grab samples were collected using a Wildco Petite Ponar Grab sampler along transects at five locations in the Clinch River arm of Watts Bar reservoir (CRM 1.3, 4.2, 7.6, 11.8, and 19.2, fig.2). These sites were selected because they provided the opportunity to relate sediment accumulation, particle size distribution, and sediment contamination data to historical data collected from these sites by the TVA in 1951, 1956, 1961, and 1991. Grab samples were collected at approximately 25 meter intervals across the transect, and the number of samples collected at each transect was a function of the width of the reservoir and the availability of sediment at that location. For example, the transect at CRM 1.3 yielded only five samples in nine attempts, and the transect at CRM 19.2 yielded only one sample in four attempts. Samples were submitted for particle size analysis, and partitioned by particle size based on the standard sieve sizes used for the analysis. After being returned from the analytical lab, samples were grouped into three broad particle size categories: less than 74 μm, 74-420 μm , and greater than 420 μm . These groupings were chosen because they approximately place grain sizes in the following categories: particle less than 74 μm are considered silts and clays; particles between 74 and 420 μm are fine to medium sands; particles greater than 420 μm are coarse sands and gravels. Each sample portion was weighed, placed in a 15 ml petri dish or 90 cm^3 aluminum can, and submitted for gamma spectrometry to determine ^{137}Cs activity.

Figure 2. Sediment grab sample locations and depths, sample ID numbers, and sediment types.



2.2 LABORATORY ANALYTICAL PROCEDURES

Samples were analyzed for critical shear stress by the Soils Laboratory at the University of California-Davis, using the Soils Laboratory erosion test standard operating procedure. Samples are prepared and analyzed as follows. While the sample was in its coring tube, a 3 inch segment of the core was sawed using a band saw, and a half-inch hole drilled through its axis. The segment was then mounted on a mandrel with end plates, the sampling tube slipped off, and the sample suspended axially in the outer plexiglass cylinder of the testing apparatus. Water from the sampling site was added to the annular space between the sample and the outer cylinder. The rotation of the outer cylinder was slowly increased until erosion to remove the thin layer of material that was altered by the shear of the sampling tube was indicated by an increase in turbidity of the water. The test began by weighing the sample on its mandrel in air. The sample was replaced in the outer cylinder and rotation at a low speed was maintained for one minute. The shear stress on the surface of the sample was read from the scale. The sample was then reweighed in air. If the weight was the same as the previous weight indicating no erosion, the rotation speed of the outer cylinder was set at a slightly higher speed and the procedure repeated.

Gamma spectrometry analysis for ^{137}Cs was conducted at the ORNL ESD RAL using either a Nuclear Data 9000 Gamma Ray Spectrometer or Genie PC with spectra acquired in 4096 channels. The samples were radiochemically analyzed using germanium solid state detectors. Counting times for each sample ranged from 60 to 1000 minutes or longer, depending on the activity level and volume of the samples.

Samples for particle-size analysis were prepared following the procedure for dry samples, ASTM D421, and analyzed following ASTM Procedure D422. Samples were passed through a variety of standard sieves, partitioned, and weighed to determine the proportion of each particle size. Grain sizes that passed through the 74 μm sieve were determined by a sedimentation process using a hydrometer to secure the necessary data.

Samples analyzed for cation exchange capacity were oxidized by adding 30 ml of 30% hydrogen peroxide solution, and warming to approximately 75°C. Samples were then analyzed following SW846, 9081A. The soil sample was mixed with an excess of sodium acetate solution, resulting in an exchange of the added sodium cations for the matrix cations. Subsequently, the sample was washed with isopropyl alcohol. An ammonium acetate concentration of displaced sodium was then determined by atomic absorption, emission spectroscopy, or an equivalent means.

Analysis for organic matter content was conducted following ASTM procedure D2974-87. Samples were oven-dried at 105°C to determine dry weights, and subsequently ashed at 440°C. Organic matter content was determined by difference as follows: organic matter, % = 100.0- ash content.

Dry density analysis was conducted following procedure SLP2 in TVA Technical Manual SM-106. The dry weight of the sample was determined by oven drying. The volume of the sample was then determined by coating it in paraffin, and measuring the volume of water displaced when the sample was submerged in water. The uncoated volume of the sample was corrected by removing the paraffin coating and subtracting its volume. The dry density was calculated by dividing the weight of the dry sample by the volume of the uncoated specimen in cm^3.

Moisture content was determined by ASTM 4959. The difference between the masses of the moist and oven-dried specimens was used as the mass of water contained in the specimen. The water content (expressed as a percentage) was determined by dividing the mass of water by the mass of soil, multiplied by 100. It should be noted that by this process, particularly moist samples result in moisture content percentages greater than 100%.

Porosity was determined by equation using the moisture content and specific gravity of the sample (ASTM D854), and the specific gravity of water.

2.3 SAMPLE IDENTIFICATION

Sediment samples for this project were identified using a six-digit master sample identification number. The numbers were assigned in the field in the order the samples were collected, beginning with 132200. For core samples, the last two digits of the number were reserved for the individual core sections, and were assigned according to the depth of the section in the core. For example, 01 were the last two digits of the ID number for the 0-6 cm section of each core, 02 were the last two digits assigned to the 6-12 cm section, etc. The five cores partitioned into 2 cm sections for particle size analysis had identification numbers assigned by the same scheme, except 01 were the last two digits assigned to the 0-2 cm section, 02 were the last two digits assigned to the 2-4 cm section, etc.

In addition to the six-digit sample identification number, individual core sections (and subsections) were assigned a suffix letter which defined the analysis performed on the sample. The letters were assigned as follows:

C	organic matter content
D	dry density
E	cation exchange capacity
G	gamma spectroscopy
S	particle size distribution/settling velocity
H	critical shear stress
D	moisture content
K	porosity

Sediment grab samples were identified only by the six-digit master ID number and letter suffix.

3.0 RESULTS

3.1 SEDIMENT CORE DATA

Sample collection and processing information for sediment core samples is described in Sect. 2.1.1, above. Results of laboratory analytical tests of core samples from Singleton Laboratory for cation exchange capacity, particle size analysis, dry density, moisture content, porosity, organic matter content, and settling velocity are listed in technical reports from Singleton Laboratories separately from this report. Appendix 1 of this report is an index of sediment core identification numbers and the laboratory analysis performed on the samples, grouped by site and sediment type. The index provides information that links core samples by site, and describes where comparative parameter values can be obtained from the raw data tables. Since either 3 or 4 core samples were collected at each site to complete all analysis, comparing parameter values at, or among sites requires looking at data values of core samples with different identification numbers. For example, particle size data at the soft mud site at TRM 538.4 were obtained from sample 135000, critical shear stress values were obtained from sample 135100, and ^{137}Cs activities were obtained from sample 135200.

Appendix 2 presents a general summary of data from sediment core samples that are grouped by site within sediment types. Settling velocity data are presented separately in SL Report 209-012-004E. Due to the varying length of the cores collected at each site, comparable data are not available for every section of each core. For example, if the core collected at one site for the gamma count was 12 cm longer than the corresponding core collected at the same site for particle size analysis, comparable data for those parameters is unavailable for the bottom two sections of the cores.

The core samples collected from sites representing each of the five sediment types that were partitioned into 2 cm sections were analyzed only for particle size distribution. Those data are available both in tables and graphically in the Singleton Laboratory technical report (SL Report 209-012-004A), and are listed by site and sediment type in appendix 3.

Data tables for ^{137}Cs and critical shear stress are attached as appendices 4 and 5 to this document. **(gamma data forthcoming from database management group).**

(Antoinette, can you provide a brief description of how the data from the following parameters are used by the models?)

Critical Shear Stress

Critical shear stress data are displayed in both tabular and graphical form in appendix 5. The Soils Laboratory reported having difficulty testing samples collected at several sites due to the uncohesive nature of the samples. Conducting the laboratory analysis required that samples be sufficiently cohesive to maintain their form when removed from the core tube and placed on a mandrel in the test cylinder. In addition, the inclusion of organic material in some samples tended to make them disintegrate rather than erode. Critical shear stress values at the sandy mud sites at TRM 556 and 534.4 were estimated due to incomplete data, and the sandy mud site at CRM 6.7 was not analyzed at all. Similarly, all three sand/gravel samples fell apart while testing, and no data are available.

Critical shear stress values varied widely, from an estimated value of 1 dyne/cm^2 to a maximum of 68 dyne/cm^2. **(Antoinette, what do these numbers represent and what is their significance?)** Values for soft mud samples ranged from 30 to 52 dyne/cm^2, and submerged soil values ranged from 12 to 30dyne/cm^2. In cohesive mud samples, critical shear stress values varied much more widely, from 7 to 68 dyne/cm^2. Only two critical shear stress values were obtained from sandy mud sites, and both were estimated (1, and <15dyne/cm^2). No values were obtained from sand/gravel sites.

^{137}Cs Activities

Sediment cores were processed in the ESD laboratory as described in Sect. 2.1.1. Six centimeter core sections were submitted to the RAL for gamma spectrometry analysis, and composite core activities were calculated by summing the total activities of each section, and dividing by the total sediment weight. If replicate counts of core sections were made, the average of the two counts was used in all statistical calculations. Activities of ^{137}Cs in sediment cores ranged from less than 1 pCi/g in some cores, to high values of 27.39 and 32.65 pCi/g in two cores collected at CRM 4.2 (132500) and CRM 6.7 (133100) respectively. Activities generally tended to increase with depth in the sediment, and showed peak values in subsurface sediments that often greatly exceeded concentrations near the surface. That trend (fig. 3) is consistent with the results of Olsen et al. (1992), and others, who found ^{137}Cs accumulated primarily deep in the sediment, and to be reflective of the historical release of contaminants from White Oak Creek in the 1950s and 1960s. The highest activities for individual core sections were obtained from the two cores listed above, 41.96 and 48.10 pCi/g.

Table 1 presents composite ^{137}Cs activities of sediment cores, grouped by sediment type. Data for individual core sections are presented in appendix 2. When categorized by sediment type, cohesive mud sites had the highest mean ^{137}Cs activities (11.09±9.33 pCi/g), followed by sandy mud (10.96± 18.78 pCi/g), soft mud (6.93± 1.53 pCi/g), submerged soil (1.79± 1.51 pCi/g), and sand/gravel sites (1.19± 1.69 pCi/g). Since these data are highly variable and only three samples were collected for each sediment type (five samples for cohesive mud), caution should by used in drawing conclusions about their representativeness. For example, the activity of the sandy mud sample collected at CRM 6.7 (sample #133100) was more than 32 pCi/g, while the activities of the two remaining sandy mud samples was less than 1 pCi/g. Furthermore, the particle size data indicate that although this sample was classified as sandy mud, its sand content is significantly lower than the other sandy mud samples, and perhaps it should more appropriately be classified as a cohesive mud sample. This possibility is supported by the sample processing information in the field logbook that describe this sample as "thick" and "cohesive" with some sandy grit. If sample 133100 is considered a cohesive mud sample rather than a sandy mud sample, the mean ^{137}Cs value for the remaining sandy mud samples is 0.12 pCi/g and the mean value for cohesive mud samples is 14.68 pCi/g. In addition to high variability, short sediment cores collected at the sand/gravel, and submerged soil sites yielded only 6 and 7 core sections, and provide limited data for analysis. In order to make accurate statements about the correlation between sediment type and radionuclide activity, more core profiles are required.

Figure 3. CESIUM ACTIVITY OF SEDIMENT CORES BY CORE DEPTH

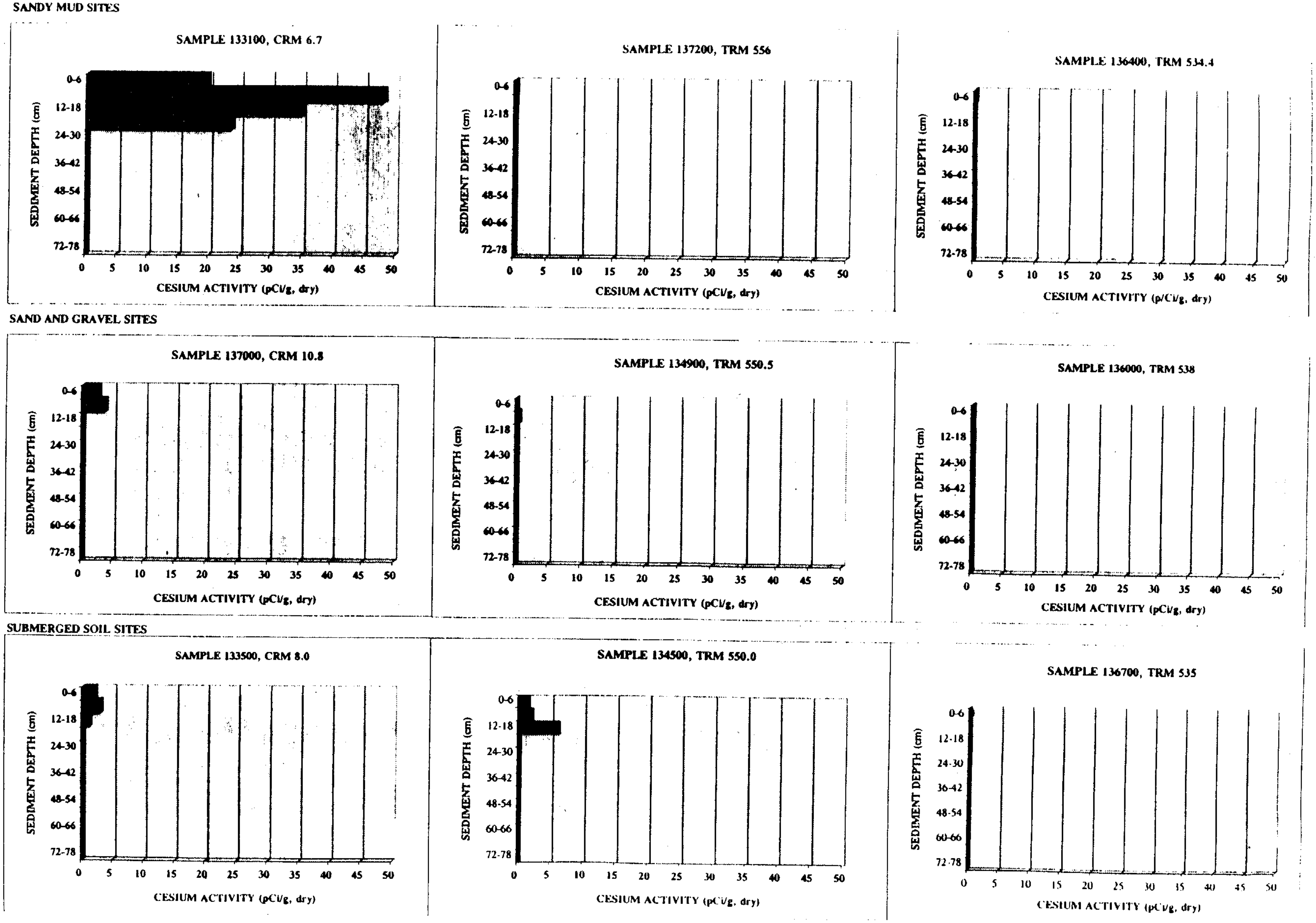
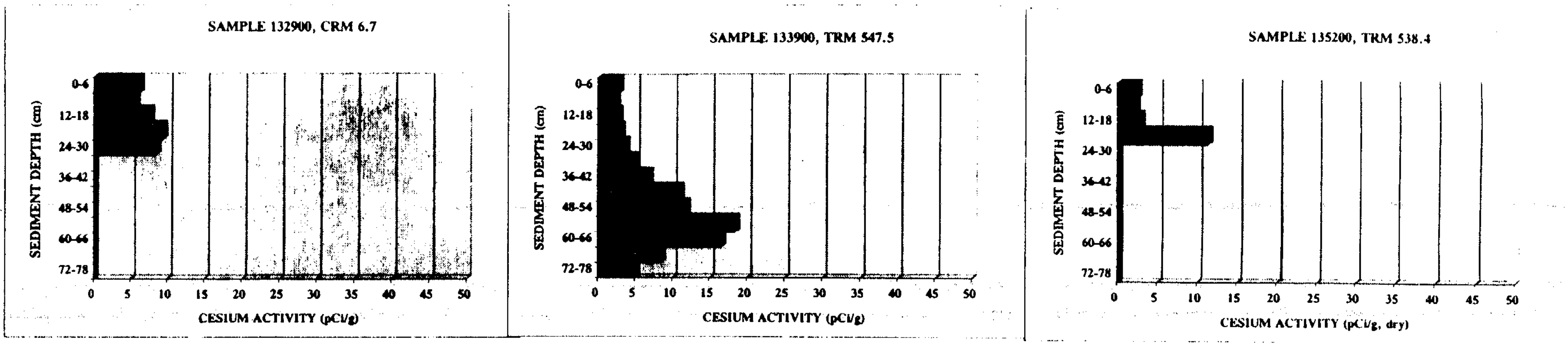


Figure 3. CESIUM ACTIVITY OF SEDIMENT CORES BY CORE DEPTH.

SOFT MUD SITES



COHESIVE MUD SITES

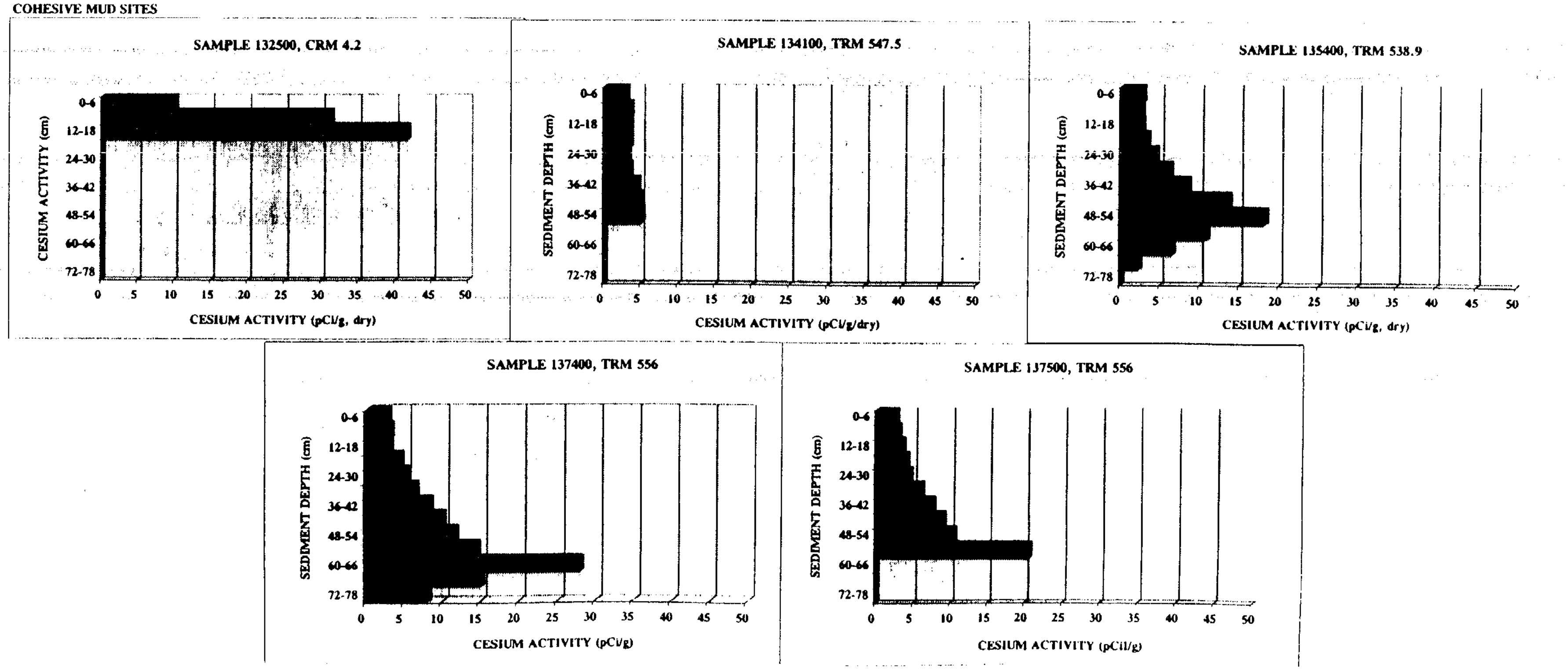


Table 1. ^{137}Cs activities of Sediment Cores by Sediment Type.

Sample ID	Location	Sediment Type	^{137}Cs Activity (pCi/g)
132900	CRM 6.7	Soft Mud	7.55
133900	TRM 547.5	Soft Mud	8.05
135200	TRM 538.4	Soft Mud	5.18
132500	CRM 4.2	Cohesive Mud	27.39
134100	TRM 547.5	Cohesive Mud	3.95
135400	TRM 538.9	Cohesive Mud	7.39
137400	TRM 556	Cohesive Mud	9.55
137500	TRM 556	Cohesive Mud	7.16
133100	CRM 6.7	Sandy Mud	32.65
136400	TRM 534.4	Sandy Mud	0.15
137200	TRM 556	Sandy Mud	0.09
134900	TRM 550.5	Sand/Gravel	0.36
136000	TRM 538	Sand/Gravel	0.07
137000	CRM 10.8	Sand/Gravel	3.14
133500	CRM 8.0	Submerged Soil	1.93
134500	TRM 550	Submerged Soil	3.23
136700	TRM 535	Submerged Soil	0.21

Organic Matter Content

Results of analysis for organic matter content ranged from about 1-8% of dry weight. Cohesive and soft mud samples showed similar results with mean values of 7.13 and 6.28% respectively. Sandy mud, submerged soil, and sand/gravel samples had somewhat lower mean values of 3.55, 3.29, and 2.63%.

Cation Exchange Capacity

Values for cation exchange capacity ranged from 3.48 meq/100g dry weight at the sand/gravel site at TRM 538, to 33.01 meq/100g at the cohesive mud site at TRM 538.9. Average values when categorized by sediment type were as follows (in meq/100g dry weight): cohesive mud, 29.08; soft mud, 23.35, submerged soil, 15.07; sandy soil, 13.51; and sand/gravel, 9.61.

Dry Density, Percent Moisture Content, and Porosity

The analytical results for the physical characteristics of dry density, percent moisture content, and porosity are summarized in table 2, below. The values listed in the table are means and standard deviations for the parameters listed by sediment type. These characteristics are related, in that samples with greater densities generally contain less moisture and have fewer void spaces. In general, the soft mud and cohesive mud samples had similar physical characteristics (lower densities, higher moisture content and porosity), and are different as a group from the sandy mud, sand/gravel, and submerged soil samples (higher densities, lower moisture contents and porosities).

Table 2. Means and standard deviations for dry density, percent moisture content, and porosity by sediment type.

Sediment Type	Dry Density		Percent Moisture Content	Porosity
	pcf	g/cm^3		
Soft Mud	44.70±14.60	0.72±0.23	84.17±28.13	0.72±0.09
Cohesive Mud	39.46±9.68	0.63±0.16	107.52±24.63	0.75±0.05
Sandy Mud	78.34±11.18	1.25±0.18	35.30±9.45	0.51±0.07
Sand/gravel	80.67±4.62	1.29±0.07	28.84±3.83	0.49±0.03
Submerged Soil	75.58±18.49	1.21±0.30	40.78±21.91	0.53±0.11

Settling Velocity

???????HELP ANTOINETTE!!

3.2 SEDIMENT GRAB SAMPLE DATA

Table 3 presents a summary of ^{137}Cs data for surface grab samples by collection site. The highest activity for both an individual sample (139000) and the mean value for a transect was found at CRM 4.2 (61.19 and 10.57 pCi/g, respectively). The activity of sample 139000 is nearly 6 times greater than any other sample collected from that transect. If it is considered an outlier and is not included in the calculation, the mean value of samples collected at CRM 4.2 falls to 6.36±3.96 pCi/g.

Table 3. Summary data of ^{137}Cs for Sediment Grab Samples.

Transect Site	Number of Samples	Min,Max	Mean
CRM 1.3	5	1.85, 17.69	8.72±7.49
CRM 4.2	13	0.88, 61.19	10.57±15.67
CRM 7.6	8	2.21, 13.89	5.05±3.68
CRM 11.8	4	1.00, 5.54	2.45±2.10
CRM 19.2	1	0.40	0.40

As discussed in Sect. 2.1.2 above, grab samples collected from sites in the Clinch River were partitioned into three broad particle size categories (<74µm , 74-420µm , and >420µm), and analyzed to determine ^{137}Cs activity. These data are shown in appendix 6 with accompanying particle size data, and the percent of the total sample weight for each particle size category. If sufficient sample was available, duplicates were submitted to ESD RAL and appear as repeated values in the appendix. Some samples had no (or too few) particles in excess of 420µm, and consequently, no data for that size category are listed. These data are summarized in table 4 below.

Table 4. Surface Grab Samples, ^{137}Cs activities: Max., min., mean, median, Percent Total Sample Mass, Percent Total Sample Activity, and Percent Mass:Percent Activity Ratio by particle size category.

Particle Size Category	Max, Min (pCi/g)	Mean (pCi/g)	Median (pCi/g)	Percent Total Sample Mass	Percent Total Sample Activity	Percent Mass:Percent Activity Ratio
<74µm, N=31	0.40, 74.20	10.28±13.18	6.16	51.84	87.79	1:1.69
74-420µm, N=31	0.20, 8.23	2.24±1.76	1.75	37.24	10.70	1:0.29
>420µm, N=21	0.03, 12.37	3.13±2.90	2.44	10.92	1.51	1:0.1

The results show that the highest ^{137}Cs activities were associated with the smallest particle sizes. Approximately 52% of the mass of all surface grab samples consisted of particles <74µm, but that sample portion accounted for nearly 88% of the total ^{137}Cs activity. The two larger particle size categories contained about 37% and 11% of the total sample mass, but accounted for only 11% and 1.5% of the total activity. These results are consistent with previous studies (Olsen et al., 1992, and Struxness et al., 1967) that have shown ^{137}Cs is preferentially associated with fine particles in aquatic environments. The affinity of contaminants for smaller particles is displayed in table 4 as a ratio of percent of the sample mass to percent of the sample activity. ^{137}Cs values ranged from less than 1 pCi/g in many sample portions, to a maximum of 74.2 pCi/g in the

<74μm sample portion collected at CRM 4.2. The mean ^{137}Cs activity for all sediment particles less than 74μm was 10.28 pCi/g, and the 74-420, and >420μm particle sizes had similar mean activities of 2.24 and 3.13 pCi/g, respectively. An analysis of variance conducted on the ^{137}Cs results of the three particle size categories determined that there was no significant difference between the mean values of the two larger particle size groups, but that the <74μm category was significantly different from the other two groups. A frequency distribution of grab samples by sediment size is displayed in figure 4. The maximum activity in each size category was obtained from sample 139000 collected at CRM 4.2. The mean value for all three particle sizes was sensitive to the highest activity obtained in its respective size category, indicating those maximum values may be outliers. When the maximum values were removed, the means for the <74 and 74-420μm particle sizes decreased to 8.23 and 1.74 pCi/g, decreases of 20% and 22%respectively. The >420μm particle size mean was somewhat less sensitive to its highest value, decreasing about 12%, to 2.67 pCi/g.

Previous studies (Olsen, et al., 1992, Turner et al., 1985, Struxness et al., 1967) indicated that ^{137}Cs is concentrated in river channels and deep water sections of the river/reservoir system. Figure 5 shows ^{137}Cs values and relative water depth at the collection site for grab samples by river transect. Since only one sample was obtained at CRM 19.2, the graph of that transect was omitted. Two samples (139000 at CRM 4.2, and 140000 at CRM 7.6) stand out as having significantly higher activities than surrounding samples collected from the same transect at similar water depths. While no sample was obtained in either attempt at the sites directly adjacent to sample 140000 for direct comparison, the activity of sample 139000 is greater than that of the surrounding samples by approximately a factor of 5.5. To compare ^{137}Cs activities of samples collected in the river channel to those collected in shallower river portions, the mean value of two groups of samples was determined: those collected in more than 20 feet of water (representing the river channel), and those collected in less than 10 feet of water (representing shallower river portions). Samples collected at intermediate depths (4 samples, 10-20 ft.) were not included in this analysis. With the exception of the transect at CRM 19.2 where only one sample was obtained, each of the other transects had a maximum water depth in excess of 30 feet. Figure 2 and information from the field logbook were used to group the samples. The mean activity of shallow water grab samples ($N = 9$) was 2.65 ± 1.64 pCi/g, compared to 7.60 ± 13.89 pCi/g for samples collected in the river channel ($N = 18$). A two-sample t-test indicated there was a significant difference in the means of the two sample groups at the $\alpha=0.05$ level ($p=0.002$). The difference remains significant ($p=0.004$) when sample 139000 is not included in the analysis.

To further measure the strength of the relationship between ^{137}Cs activity and water depth at the collection sites of samples in this study, the correlation coefficient, r, was determined to be 0.60, indicating a positive relationship between those two factors. Figure 6 is a graphical presentation of this data.

The relationship between distance from the source of contamination at White Oak Creek (CRM 20.8) and ^{137}Cs activity of surface grab samples was also investigated. The correlation coefficient, r, was determined to be 0.51, indicating a positive relationship between these factors. This relationship at first seems counterintuitive, as ^{137}Cs activities would be expected to be higher

FIG. 4 FREQUENCY DISTRIBUTION OF OF CS-137 BY PARTICLE SIZE

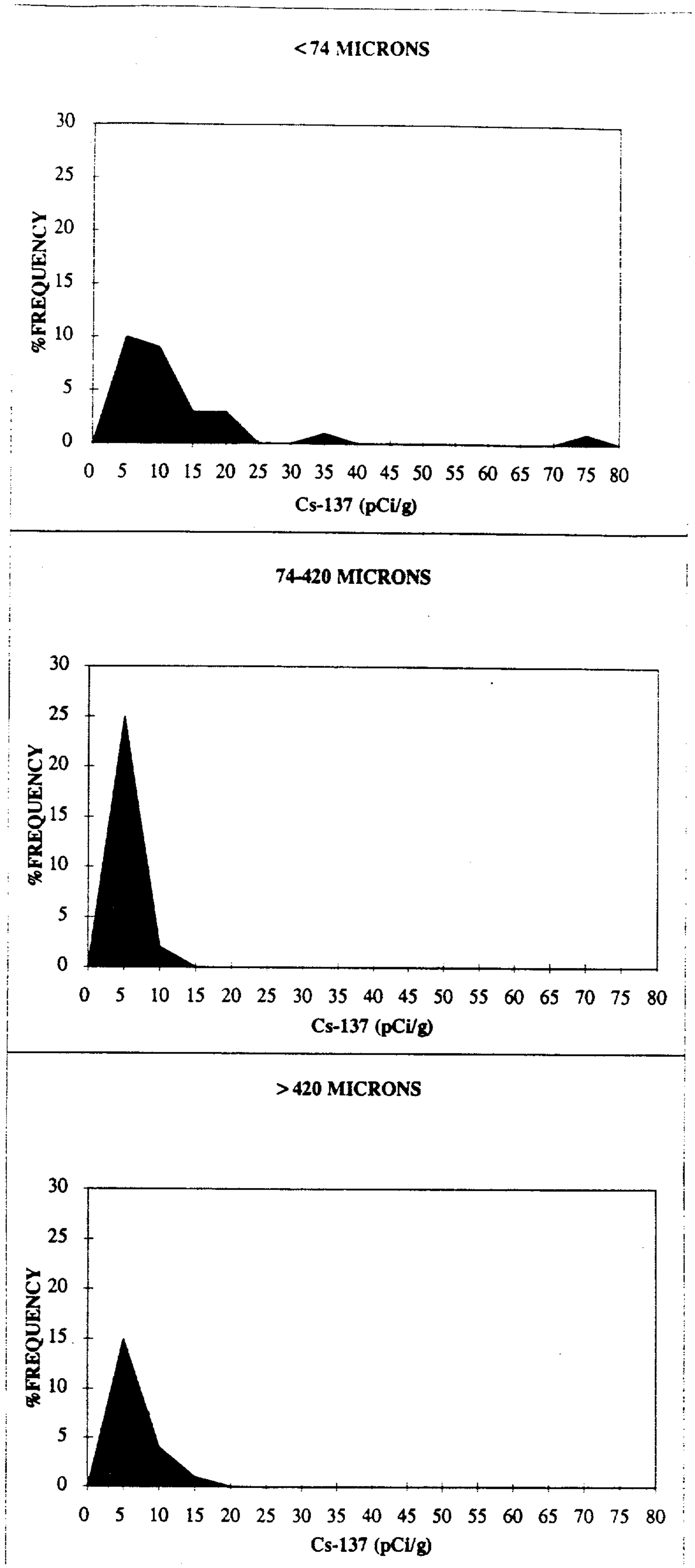
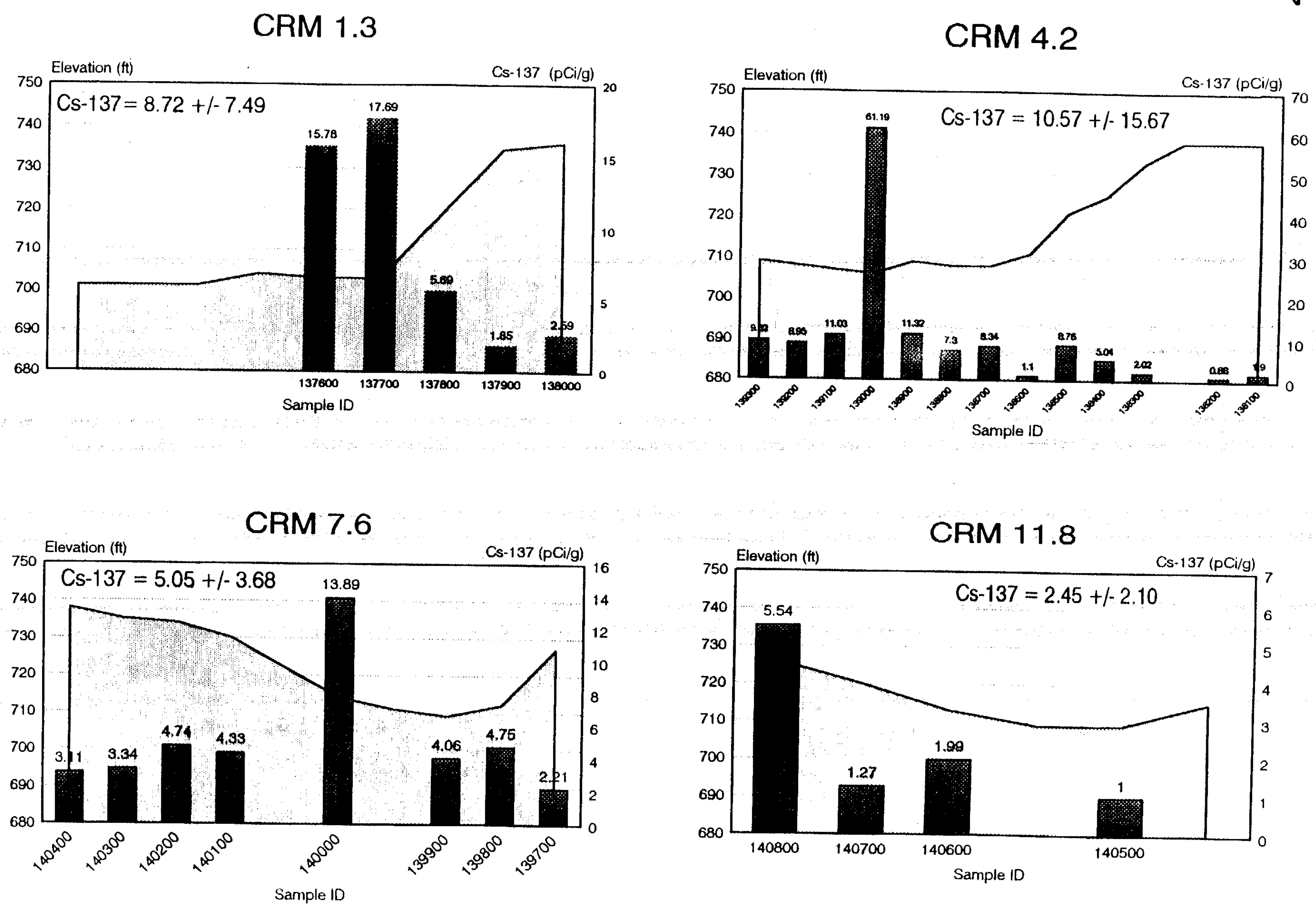
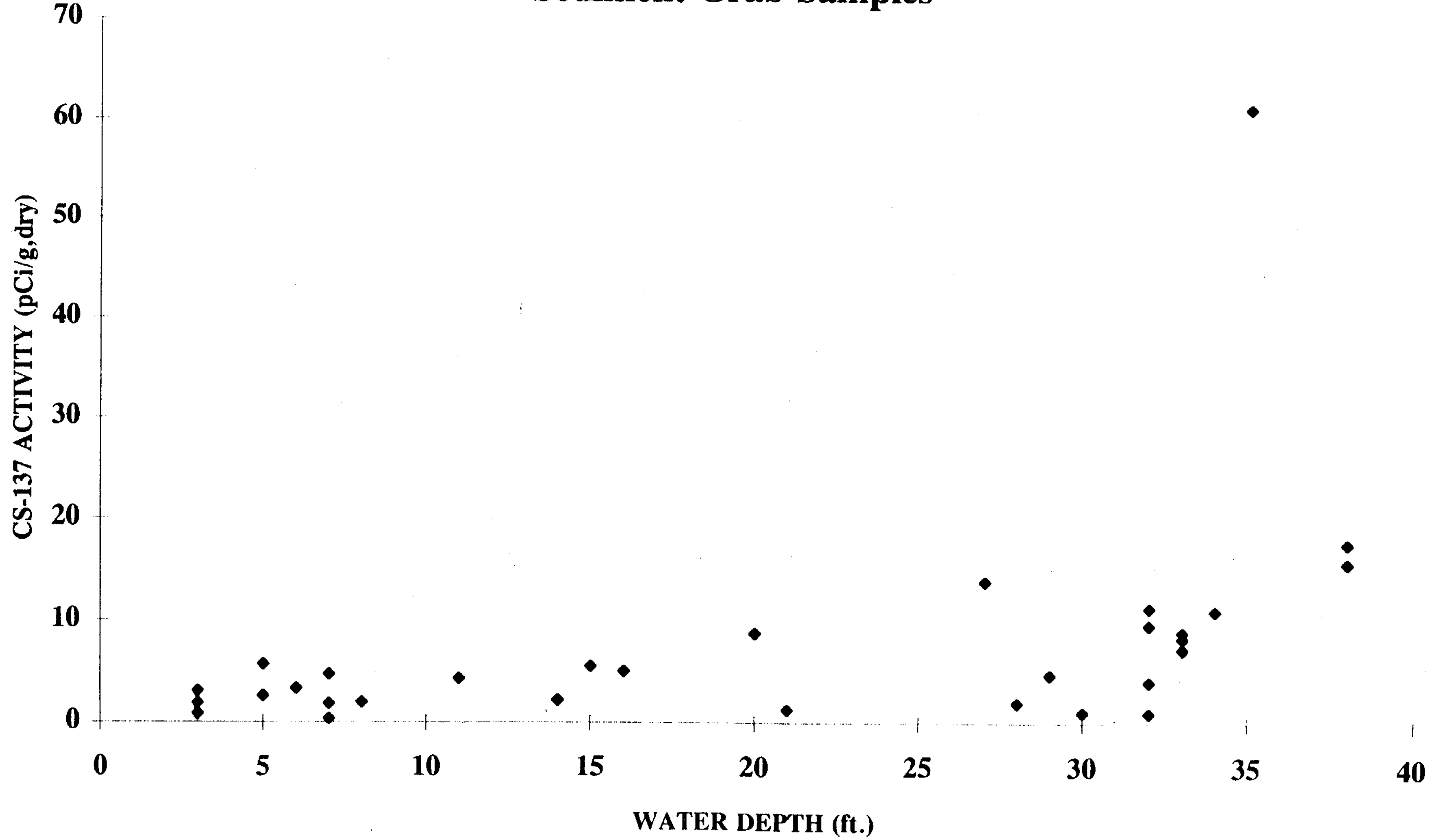


Figure 5. Cs-137 values and relative water depths by Transect for surface grab Samples.



Cs-137 concentrations along bottom profile

Fig.6 Cesium Activity by Water Depth at Collection Sites for Sediment Grab Samples



closer to the source of contamination. However, as pointed out by Levine et al. (1994), deposition of finer particles, to which ^{137}Cs has an affinity, does not occur much in the Clinch River until downstream of the Poplar Creek confluence at CRM 12. Furthermore, the river channel (deeper river portions) are more likely to be deposition zones, which would also help explain the relationship between river depth and ^{137}Cs activities.

4.0 CONCLUSIONS

As part of the Clinch River Environmental Restoration Program's assessment of contaminants downstream from the Oak Ridge Reservation, 15 sediment core and 31 surface grab samples were collected from sites in the Clinch River/Watts Bar Reservoir system. The samples were analyzed for ^{137}Cs activity, particle size distribution, organic matter content, cation exchange capacity, critical shear stress, dry density, percent moisture content, porosity, and settling velocity. The results of the ^{137}Cs data were consistent with earlier studies that indicated ^{137}Cs is concentrated in the deep water channels of the river/reservoir system, and that activities tend to increase with depth in the sediment, reflecting historical contaminant releases. The highest ^{137}Cs values in sediment cores were found in finer-grained soft mud and cohesive mud samples, and lower concentrations were found in larger-grained submerged soil and sand/ gravel samples. Surface grab samples (representing approximately the top 10 cm of the sediment) were collected at 5 transects in the Clinch River arm of Watts Bar Reservoir, partitioned into three particle size categories (<74μm , 74-420μm, and >420μm), and analyzed for ^{137}Cs. The highest activities in the grab samples were associated with the smallest particle sizes. Approximately 52% of the mass of all grab samples consisted of particles <74μm, but contained nearly 88% of the total ^{137}Cs activity. The two larger particle size categories contained 37% and 11% of the total sample mass, but only 11% and 1.5%, respectively, of the total ^{137}Cs activity. Along with the ^{137}Cs data, the physical data collected for this task will be used to supplement an ongoing modeling activity designed to characterize how sediments and their associated contaminants move into and through the Clinch River/Watts Bar Reservoir system.

5.0 REFERENCES

Arulanandan, K., Loganathan, P., Krone, Ray B., "Pore and Eroding Fluid Influences on Surface Erosion of Soil", *Journal of the Geotechnical Engineering Division*, ASCE, Vol. 101, No. GT1., Proceedings Paper 11078, pp. 51-66, Jan. 1975.

1991 Annual Book of ASTM Standards, Vol. 11.04, ASTM, Philadelphia, PA, 1991.

Levine, D.A., W.W. Hargrove, K.R. Campbell, M.A. Wood, and C.D. Rash. 1994. *Data Summary for the Near-Shore Sediment Characterization Task of the Clinch River Environmental Restoration Program,* ORNL/ER-264, Martin Marietta Energy Systems, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Olsen, C.R., I.L. Larsen, P.D. Lowry, C.R. Moriones, C.J. Ford, K.C. Dearstone, R.R. Turner, B.L. Kimmel, and C.C. Brandt 1992. *Transport and Accumulation of ^{137}Cs and Mercury in the Clinch River and Watts Bar Reservoir System,* ORNL/ER-7, Martin Marietta Energy Systems, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Quality Assurance Manual, Vol. 1, Rev. 7, United Energy Services Corporation, 1992.

Struxness, E.G., P.H. Carrigan, Jr., M.A. Churchill, K.E. Cowser, F.J. Morton, D.J. Nelson, and F.L. Parker. 1967. *Comprehensive Report of the Clinch River Study*, ORNL-4035, Martin Marietta Energy Systems, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Technical Manual-SM 106 3rd ed., Engineering Soil Testing, TVA Division of Construction, Singleton Materials Engineering Lab, Knoxville, TN, Sept. 1978.

Test Methods for Evaluating Solid Waste, Vol. IC: Laboratory Manual, Physical/Chemical Methods, SW-846, 3rd ed. EPA, Office of Solid Waste and Emergency Response, Washington, D.C., 1986.

Turner, R.R., C.R. Olsen, and W.A. Wilcox, Jr. 1984. "Environmental Fate of Hg and ^{137}Cs Discharged from Oak Ridge Facilities." In Hemphill, D.D. ed. *Trace Substances in Environmental Health-XVIII, 1984. A Symposium.* Univ. of Missouri, Columbia.

APPENDIX 1

Index of Sediment Core Identification Numbers, Collection Sites, Sediment Types, and Laboratory Analysis.

Index of sediment core master IDs, collection site, sediment type, and lab analysis.

SAMPLE ID	LAB ANALYSIS
CLINCH RIVER MILE 6.7, SOFT MUD SITE	
132600	1
132700,132800 (duplicate)	3,4,5,6,7,8,9
132900	2
TENNESSEE RIVER MILE 547.5, SOFT MUD SITE	
133600	3,4,5,6,7,8,9
133700	10
133800	1
133900	2
TENNESSEE RIVER MILE 538.4, SOFT MUD SITE	
135000	3,4,5,6,7,8,9
135100	1
135200	2
CLINCH RIVER MILE 4.2, COHESIVE MUD SITE	
132200, 132300 (duplicate)	1
132400	3,4,5,6,7,8,9
132500	2
TENNESSEE RIVER MILE 556.0, COHESIVE MUD SITE	
137400, 137500 (duplicate)	2
TENNESSEE RIVER MILE 547.5, COHESIVE MUD SITE	
134000	1
134100	2
134200	3,4,5,6,7,8,9
TENNESSEE RIVER MILE 538.9, COHESIVE MUD SITE	
135300	1

1, critical shear stress, appendix 5
2, ^{137}Cs, appendix 4
3, organic matter content, SL Report 209-012-004D, page 3
4, particle size distribution, SL Report 209-012-004A, page 3
5, dry density, SL Report 209-012-004B, page 2
6, moisture content, SL Report 209-012-004B, page 6
7, porosity, SL Report 209-012-004B, page 8
8, cation exchange capacity, SL Report 209-012-004A, page 2
9, settling velocity, SL Report 209-012-004E, page 2
10, particle size distribution, SL Report 209-012-004C, page 2

Index of sediment core master IDs, collection site, sediment type, and lab analysis.

SAMPLE ID	LAB ANALYSIS
135400	2
135500	3,4,5,6,7,8,9
135600	10
CLINCH RIVER MILE 6.7, SANDY MUD SITE	
133000	1
133100	2
133200	3,4,5,6,7,8,9
TENNESSEE RIVER MILE 556.0, SANDY MUD SITE	
137100	1
137200	2
137300	3,4,5,6,7,8,9
TENNESSEE RIVER MILE 534.4, SANDY MUD SITE	
136100	1
136200	3,4,5,6,7,8,9
136300	10
136400	2
CLINCH RIVER MILE 10.8, SAND AND GRAVEL SITE	
136800	1
136900	3,4,5,6,7,8,9
137000	2
TENNESSEE RIVER MILE 550.5, SAND AND GRAVEL SITE	
134700	3,4,5,6,7,8,9
134800	1
134900	2
TENNESSEE RIVER MILE 538.0, SAND AND GRAVEL SITE	
135700	1

1, critical shear stress, Appendix 5
2, ^{137}Cs, Appendix 4
3, organic matter content, SL Report 209-012-004D, page 3
4, particle size distribution, SL Report 209-012-004A, page 3
5, dry density, SL Report 209-012-004B, page 2
6, moisture content, SL Report 209-012-004B, page 6
7, porosity, SL Report 209-012-004B, page 8
8, cation exchange capacity, SL Report 209-012-004A, page 2
9, settling velocity, SL Report 209-012-004E, page 2
10, particle size distribution, SL Report 209-012-004C, page 2

Index of sediment core master IDs, collection site, sediment type, and lab analysis.

SAMPLE ID	LAB ANALYSIS
135800	3,4,5,6,7,8,9
135900	10
136000	2
CLINCH RIVER MILE 8.0, SUBMERGED MUD SITE	
133300	3,4,5,6,7,8,9
133400	1
133500	2
TENNESSEE RIVER MILE 550.0, SUBMERGED SOIL SITE	
134300	1
134400	3,4,5,6,7,8,9
134500	2
134600	10
TENNESSEE RIVER MILE 535, SUBMERGED SOIL SITE	
136500	1
136600	3,4,5,6,7,8,9
136700	2

1, critical shear stress, Appendix 5
2, ^{137}Cs, Appendix 4
3, organic matter content, SL Report 209-012-004D, page 3
4, particle size distribution, SL Report 209-012-004A, page 3
5, dry density, SL Report 209-012-004B, page 2
6, moisture content, SL Report 209-012-004B, page 6
7, porosity, SL Report 209-012-004B, page 8
8, cation exchange capacity, SL Report 209-012-004A, page 2
9, settling velocity, SL Report 209-012-004E, page 2
10, particle size distribution, SL Report 209-012-004C, page 2

APPENDIX 2

Sediment Core Data Summary by Collection Site

Sediment collection depth, organic matter content, dry density, percent moisture content, porosity, critical shear stress, cation exchange capacity (cec), percent gravel:sand:silt:clay, and ^{137}Cs activity for sediment core samples.

sediment depth, cm	organic matter content, % dry weight	dry density		% moisture content	porosity	critical shear stress, dyne/cm^2	cec, meq/100g dry weight	percent gr:sa:si:cl	^{137}Cs, pCi/g
		pcf	g/cm^3						
Clinch River Mile 6.7, Soft Sediment Site, water depth 12 ft., samples 132600, 132700, 132900									
0-6	5.1	62.4	0.9996	53.6	0.6214	52		0:3:65:32	6.29, 6.04*
6-12	4.5	61.3	0.982				14.71	0:5:68:27	5.59
12-18	4.7	57.7	0.924	58.8	0.6472			0:5:68:27	7.61
18-24	4.6	57.5	0.921					0:6:62:32	9.36
24-30	5	47.9	0.767					0:6:66:28	8.47
30-36	4.3	53.8	0.862					0:9:69:22	
36-42	5	52.6	0.843	79.6	0.6784			0:8:70:22	
Clinch River Mile 6.7, Soft Sediment Site (duplicate), water depth 12 ft., samples132600,132800,132900									
0-6	5.2	59.2	0.948	53.0	0.6367	52		0:3:61:36	6.29, 6.04*
6-12	4.9	66.2	1.06				15.56	0:3:65:32	5.59
12-18	4.4	62.7	1.004	54.5	0.6181			0:6:62:32	7.61
18-24	4.5	60	0.961					0:5:62:33	9.36
24-30	5.1	54.1	0.867					0:4:64:32	8.47
30-36	5.4	56.1	0.899					0:5:68:27	
36-42	5.2	59.2	0.948	61.7	0.6408			0:8:71:21	
42-46	4.8	49.8	0.798					0:4:74:22	
Tennessee River Mile 547.5, Soft Sediment Site, water depth 38 ft., samples 133600,133800,133900									
0-6	7.7	51.8	0.83	68.3	0.6784	30		0:2:23:75	2.69, 2.89*
6-12	7.4	41.9	0.671				31.26	0:1:21:78	2.35
12-18	8	38.3	0.614	112.7	0.7711			0:1:23:76	2.7
18-24	7	36.6	0.586					0:1:23:76	2.97
24-30	7.5	35.2	0.564					0:2:21:77	3.67
30-36	7.7	34.1	0.546					0:2:22:76	4.73
36-42	8.1	31.1	0.498	129	0.8155			0:1:17:82	6.75

* Replicate gamma count
** Sample inappropriate for analysis
*** Estimate based on incomplete data
\# Duplicate sample

Sediment collection depth, organic matter content, dry density, percent moisture content, porosity, critical shear stress, cation exchange capacity (cec), percent gravel:sand:silt:clay, and ^{137}Cs activity for sediment core samples.

sediment depth, cm	organic matter content, % dry weight	dry density		% moisture content	porosity	critical shear stress, dyne/cm^2	cec, meq/100g dry weight	percent gr:sa:si:cl	^{137}Cs, pCi/g
		pcf	g/cm^3						
42-48	8.1	27.4	0.439					0:2:24:74	10.97
48-54	7.5	28.6	0.458					0:3:29:68	11.79
54-60	7.9	30.8	0.493					0:3:23:74	18.39
60-66	8	28.4	0.455					0:2:24:74	16.54
66-72	8.5	26.3	0.421					0:7:24:69	8.37
72-79	8.3	21.6	0.346					0:5:29:66	4.96
Tennessee River Mile 538.4, Soft Sediment Site, water depth 12 ft., samples 135000, 135100, 135200									
0-6	8.1	36.2	0.58	109.3	0.7836	30		0:3:23:74	2.04,2.96*
6-12	7	34.5	0.553				31.85	0:4:19:77	2.24
12-18	8.2	31.4	0.503	147.8	0.8035			0:10:26:64	2.83
18-24	7.1	21.8	0.349	231.7	0.8641			0:18:33:49	11.27
Clinch River Mile 4.2, Cohesive Sediment Site, water depth unknown, samples 132200,132300,132400,132500									
0-6	5.3	45.9	0.7353	89.3	0.7194	9, 7#		0:2:51:47	10.07
6-12	5.9	51.2	0.8202				22.65	0:2:54:44	31.26
12-18	5.6	47	0.7529	85.6	0.7252			0:5:53:42	41.27, 41.96*
18-24	6.2	47.4	0.7593					0:5:53:42	
24-30	6	50.9	0.8154					0:5:56:39	
30-36	5.3	60	0.9611	63.1	0.6317			0:17:54:29	
Tennessee River Mile 556, Cohesive Sediment Site, water depth 49 ft., Gamma scan only, sample 137400									
0-6									2.68
6-12									3.02
12-18									2.95
18-24									4.34
24-30									5.12
30-36									6.36

* Replicate gamma count

** Sample inappropriate for analysis

*** Estimate based on incomplete data

// Duplicate sample

Sediment collection depth, organic matter content, dry density, percent moisture content, porosity, critical shear stress, cation exchange capacity (cec), percent gravel:sand:silt:clay, and ^{137}Cs activity for sediment core samples.

sediment depth, cm	organic matter content, % dry weight	dry density		% moisture content	porosity	critical shear stress, dyne/cm^2	cec, meq/100g dry weight	percent gr:sa:si:cl	^{137}Cs, pCi/g
		pcf	g/cm^3						
36-42									8.23
42-48									9.92
48-54									11.58
54-60									14.44
60-66									27.82
66-72									14.97
72-78									8.05
Tennessee River Mile 556, Cohesive Mud Site (duplicate sample), water depth 49 ft., Gamma scan only, sample 137500									
0-6									2.51, 2.67*
6-12									2.88
12-18									3.46
18-24									3.97
24-30									4.44
30-36									5.98
36-42									7.54
42-48									8.96
48-54									10.39
54-58									20.46
Tennessee River Mile 547.5, Cohesive Mud Site, water depth unknown, samples 134000, 134100, 134200									
0-6	8.9	37.2	0.596	112	0.7672	68		0:1:19:80	2.98
6-12	8.2	36.6	0.586				31.58	0:1:21:78	3.53
12-18	7.6	36.7	0.588	114.7	0.7773			0:2:19:79	3.43
18-24	8.3	37.2	0.596					0:4:21:75	3.43
24-30	8.4	34.3	0.549					0:1:27:72	3.18
30-36	7.9	33.1	0.53					0:1:19:80	3.44

* Replicate gamma count

** Sample inappropriate for analysis

*** Estimate based on incomplete data

// Duplicate sample

Sediment collection depth, organic matter content, dry density, percent moisture content, porosity, critical shear stress, cation exchange capacity (cec), percent gravel:sand:silt:clay, and ^{137}Cs activity for sediment core samples.

sediment depth, cm	organic matter content, % dry weight	dry density		% moisture content	porosity	critical shear stress, dyne/cm²	cec, meq/100g dry weight	percent gr:sa:si:cl	^{137}Cs, pCi/g
		pcf	g/cm³						
36-42	8.6	29.2	0.468	147.9	0.8187			0:1:21:78	4.44
42-48	8.6	30.6	0.49					0:1:21:78	4.96
48-54	8.2	28.7	0.46					0:4:27:69	5.07
54-60	8.7	26.2	0.42					0:5:30:65	
60-66	4.2	22.2	0.356					0:5:28:67	
Tennessee River Mile 538.9, Cohesive Mud Site, water depth 35 ft., samples 135300, 135400, 135500									
0-6	7.7	45	0.7208	97.6	0.7444	48		0:2:25:73	2.83
6-12	6.9	37.9	0.6071				33.01	0:2:23:75	2.63
12-18	7.3	37.5	0.6007	127.7	0.7672			0:2:23:75	2.71
18-24	7.3	38.2	0.6119	129.8	0.7949			0:1:21:78	3.37
24-30	7.4	35.7	0.572					0:1:20:79	4.44
30-36	7.7	36.4	0.583					0:2:23:75	6.24
36-42	8.2	32.9	0.527					0:3:25:72	8.52
42-48	8.4	33.6	0.538					0:4:39:57	13.6
48-54	8.5	26.5	0.425					0:8:33:59	18.19
54-60									10.87
60-66									6.56
66-72									2.33
Clinch River Mile 6.7, Sandy Mud Site, water depth 24 ft., samples 133000, 133100, 133200									
0-6	5.2	51.5	0.825	64.5	0.6839	**		0:8:62:30	19.61
6-12	5.4	65.3	1.046				14.55	0:17:57:26	48.1
12-18	3.9	75.3	1.206	37	0.5288			0:35:48:17	34.9
18-24	2.6	76.2	1.221	36.5	0.5341			0:63:27:10	23.57
Tennessee River Mile 556, Sandy Mud Site, water depth 10 ft., samples 137100, 137200, 137300									
0-6	1.2	90.4	1.448	27.4	0.4299	1***		0:75:13:12	0.19

* Replicate gamma count
** Sample inappropriate for analysis
*** Estimate based on incomplete data
// Duplicate sample

Sediment collection depth, organic matter content, dry density, percent moisture content, porosity, critical shear stress, cation exchange capacity (cec), percent gravel:sand:silt:clay, and ^{137}Cs activity for sediment core samples.

sediment depth, cm	organic matter content, % dry weight	dry density		% moisture content	porosity	critical shear stress, dyne/cm^2	cec, meq/100g dry weight	percent gr:sa:si:cl	^{137}Cs, pCi/g
		pcf	g/cm^3						
6-12	3	86.7	1.389	30.5	0.4596		12.78	0:28:37:35	0.08
12-18	3.2	91.2	1.461	26.4	0.4271			0:26:37:37	
Tennessee River Mile 534.4, Sandy Mud Site, water depth 15 ft., samples 136100, 136200, 136400									
0-6	3.9	78.5	1.257	31.8	0.5049	<15***	13.2	0:30:40:30	0.25
6-12									ND, (<0.05)
Clinch River Mile 10.8, Sand and Gravel Site, water depth 18 ft., samples 136800, 136900, 137000									
0-6	1.7	81	1.298	28.8	0.5009	**		0:83:11:6	2.57, 2.66*
6-12	2	72.7	1.165	29.7	0.4448		8.1	0:76:11:13	3.64
Tennessee River Mile 550.5, Sand and Gravel Site, water depth 20 ft., samples 134700, 134800, 134900									
0-6	4.2	81.7	1.309	29.9	0.5171	**		0:12:41:47	0.36
6-12	4.3	77	1.233	35	0.5201		17.25	0:35:29:36	
Tennessee River Mile 538, Sand and Gravel Site, water depth 3 ft., samples 135700, 135800, 136000									
0-6	1.5	78.7	1.261	25.8	0.5133	**		0:80:13:7	0.1
6-12	0.9	86.5	1.386	24	0.4849		3.48	0:81:12:7	0.04
12-18	3	92.2	1.477	24.7	0.4448			0:82:12:6	0.06
Clinch River Mile 8.0, Submerged Soil, water depth unknown, samples 133300, 133400, 133500									
0-6	1.6	91	1.458	27.5	0.4284	12		0:35:56:9	1.94
6-12	2	91	1.458	23.2	0.4146		14.67	0:41:41:18	2.88
12-18	2.2	98.2	1.573	24.4	0.4108			0:33:40:27	1.03
Tennessee River Mile 550.0, Submerged Soil Site, water depth unknown, samples 134300, 134400, 134500									
0-6	7.3	68.7	1.1	32.7	0.5767	30		0: 10:49:41	1.29, 1.44*
6-12	5.8	52.5	0.841				22.4	0:8:47:45	1.9
12-18	5.9	56.5	0.905	76.9	0.6546			0:4:52:44	6.01
18-24	6.3	48.2	0.772	87.8	0.696			0:27:35:38	

* Replicate gamma count

** Sample inappropriate for analysis

*** Estimate based on incomplete data

\# Duplicate sample

Sediment collection depth, organic matter content, dry density, percent moisture content, porosity, critical shear stress, cation exchange capacity (cec), percent gravel:sand:silt:clay, and ^{137}Cs activity for sediment core samples.

sediment depth, cm	organic matter content, % dry weight	dry density		% moisture content	porosity	critical shear stress, dyne/cm^2	cec, meq/100g dry weight	percent gr:sa:si:cl	^{137}Cs, pCi/g
		pcf	g/cm^3						
Tennessee River Mile 535, Submerged Soil Site, water depth 5 ft., samples 136500, 136600, 136700									
0-6	1.7	81	1.298	26.9	0.5122	28		0:13:71:16	0.21
6-12	1.5	72.7	1.165	36.1	0.5572		8.15	0:12:78:10	

* Replicate gamma count
** Sample inappropriate for analysis
*** Estimate based on incomplete data
\# Duplicate sample

APPENDIX 6

Data Summary for Sediment Grab Samples

Sediment Grab Samples: Cesium activity, percent gravel, sand, silt, and clay by particle size.

SAMPLE ID (Activity, pCi/g)	PARTICLE SIZE	PERCENT TOTAL WEIGHT	^{137}Cs ACTIVITY (pCi/g,dry)	PERCENT GR:SA:SI:CL	SAMPLE SITE	WATER DEPTH(ft)
137600 (15.78)	<74	96.17%	16.3± 0.34	0:6:63:31	CRM 1.3	38
	74-420	2.81%	1.98± 0.54			
	>420	1.02%	5.15± 1.98			
137700 (17.69)	<74	92.86%	18.9± 0.4	0:8:56:36	CRM 1.3	38
	74-420	2.93%	2.31± 0.34			
	>420	4.21%	1.65± 0.32			
137800 (5.69)	<74	88.77%	5.85±0.28	0:16:67:17	CRM 1.3	22
	<74	88.77%	6.46± 0.29			
	74-420	9.67%	1.75± 0.34			
	>420	1.56%	3.21± 0.57			
137900 (1.85)	<74	57.41%	2.84±0.06	0:48:46:6	CRM1.3	7
	74-420	42.59%	0.52±0.04			
138000 (2.59)	<74	74.51%	2.98± 0.14	0:31:62:7	CRM 1.3	5
	74-420	23.24%	1.46± 0.1			
	>420	2.24%	1.46± 0.14			
138100 (1.90)	<74	48.48%	3.7±0.16	0:63:32:5	CRM 4.2	3
	74-420	51.52%	0.2±0.04			
138200 (0.88)	<74	35.48%	2.11±0.07	0:72:24:4	CRM 4.2	3
	74-420	64.52%	0.21±0.04			
138300 (2.02)	<74	54.05%	3.64 ±0.07	0:47:46:7	CRM 4.2	8

Sediment Grab Samples: Cesium activity, percent gravel, sand, silt, and clay by particle size.

SAMPLE ID (Activity, pCi/g)	PARTICLE SIZE	PERCENT TOTAL WEIGHT	^{137}Cs ACTIVITY (pCi/g,dry)	PERCENT GR:SA:SI:CL	SAMPLE SITE	WATER DEPTH(ft)
	<74	54.05%	3.22± 0.07			
	74-420	43.38%	0.31± 0.03			
	>420	2.57%	1.32± 0.18			
138400 (5.04)	<74	52.60%	9.29±0.37	0:56:35:9	CRM 4.2	16
	74-420	47.40%	0.33±0.05			
138500 (8.76)	<74	68.26%	11.91± 0.36	0:36:51:13	CRM 4.2	20
	<74	68.26%	12.29± 0.39			
	74-420	30.67%	1.57± 0.05			
	>420	1.07%	2.44±0.66			
138600 (1.10)	<74	17.58%	4.8±0.42	0:81:14:5	CRM 4.2	30
	74-420	82.42%	0.31±0.06			
	74-420	82.42%	0.33±0.09			
138700 (8.34)	<74	79.64%	9.89± 0.31	0:24:64:12	CRM 4.2	33
	<74	79.64%	9.59± 0.3			
	74-420	19.78%	3.5± 0.07			
	>420	0.57%	2.45±0.84			
138800 (7.30)	<74	73.83%	8.37±0.43	0:26:62:12	CRM 4,2	33
	74-420	26.17%	4.27±0.27			
138900 (11.32)	<74	78.06%	13.36± 0.36	0:26:62:12	CRM 4.2	32
	<74	78.06%	13.24± 0.36			

Sediment Grab Samples: Cesium activity, percent gravel, sand, silt, and clay by particle size.

SAMPLE ID (Activity, pCi/g)	PARTICLE SIZE	PERCENT TOTAL WEIGHT	^{137}Cs ACTIVITY (pCi/g,dry)	PERCENT GR:SA:SI:CL	SAMPLE SITE	WATER DEPTH(ft)
	74-420	21.48%	4.23± 0.24			
	>420	0.46%	6.56± 1.11			
139000 (61.19)	<74	83.32%	74.2± 1.1	0:20:60:20	CRM 4.2	35
	<74	83.32%	69.38± 1.02			
	74-420	16.13%	8.23± 0.28			
	>420	0.55%	12.37± 2.08			
139100 (11.03)	<74	66.59%	16.17± 0.45	0:22:60:18	CRM 4.2	34
	<74	66.59%	14.71±0.43			
	74-420	16.25%	4.13± 0.22			
	>420	17.16%	0.58± 0.34			
139200 (8.95)	<74	69.07%	13.07± 0.4	1:24:58:17	CRM 4.2	33
	<74	69.07%	11.52± 0.38			
	74-420	12.67%	3.06± 0.17			
	>420	18.26%	0.49± 0.05			
139300 (9.62)	<74	85.92%	10.92±0.28	0:16:67:17	CRM 4.2	32
	74-420	13.92%	1.72±0.1			
	>420	0.16%	0.9±0			
139700 (2.21)	<74	39.03%	3.34±0.28	0:64:27:9	CRM 7.6	14
	74-420	60.97%	1.48±0.14			
139800 (4.75)	<74	61.27%	6.13± 0.18	0:41:48:11	CRM 7.6	29

Sediment Grab Samples: Cesium activity, percent gravel, sand, silt, and clay by particle size.

SAMPLE ID (Activity, pCi/g)	PARTICLE SIZE	PERCENT TOTAL WEIGHT	^{137}Cs ACTIVITY (pCi/g,dry)	PERCENT GR:SA:SI:CL	SAMPLE SITE	WATER DEPTH(ft)
	74-420	37.26%	2.54± 0.14			
	>420	1.47%	3.44± 0.46			
139900 (4.06)	<74	23.39%	7.73±0.4	0:79:17:4	CRM 7.6	32
	74-420	75.35%	2.99±0.18			
	>420	1.26%	0.003±0.001			
140000 (13.89)	<74	30.44%	33.63± 0.77	0:70:21:9	CRM 7.6	27
	74-420	67.61%	5.25± 0.2			
	>420	1.95%	4.87± 0.37			
140100 (4.33)	<74	25.14%	9.44±0.37	0:76:18:6	CRM 7.6	11
	74-420	74.86%	2.62±0.17			
140200 (4.74)	<74	45.60%	5.9± 0.24	0:57:34:9	CRM 7.6	7
	74-420	54.40%	3.7± 0.22			
	74-420	54.40%	3.84± 0.21			
140300 (3.34)	<74	44.59%	4.43±0.29	0:58:32:10	CRM 7.6	6
	74-420	54.62%	2.42±0.17			
	>420	0.78%	5.62±0.86			
140400 (3.11)	<74	48.79%	4.04± 0.24	0:52:37:11	CRM 7.6	3
	74-420	50.97%	2.42± 0.1			
	>420	0.25%	2.24± 0.9			
140500 (1.00)	<74	3.64%	4.1±0.34	68:27:3:2	CRM 11.8	32

Sediment Grab Samples: Cesium activity, percent gravel, sand, silt, and clay by particle size.

SAMPLE ID (Activity, pCi/g)	PARTICLE SIZE	PERCENT TOTAL WEIGHT	^{137}Cs ACTIVITY (pCi/g,dry)	PERCENT GR:SA:SI:CL	SAMPLE SITE	WATER DEPTH(ft)
	74-420	2.96%	1.13±0.1			
	>420	93.40%	0.87±0.03			
140600 (1.99)	<74	4.09%	4.67± 0.18	0:70:25:5	CRM 11.8	28
	74-420	91.91%	1.69± 0.09			
	>420	4.0%	6.21± 0.24			
140700 (1.27)	<74	44.80%	1.26±0.06	0:57:32:11	CRM 11.8	21
	74-420	55.20%	1.28±0.04			
140800 (5.54)	<74	52.31%	9.35± 0.34	0:50:38:12	CRM 11.8	15
	74-420	47.24%	1.34± 0.1			
	>420	0.45%	2.78± 0.89			
140900 (0.40)	<74	92.85%	0.39± 0.03	0:8:64:28	CRM 19.2	7
	<74	92.85%	0.42±0.03			
	74-420	6.66%	0.28± 0.05			
	>420	0.49%	1.07± 0.4			

APPENDIX 3

Particle Size Data for 2 cm Core Sections

Sample ID, sediment depth, and percent gravel:sand:silt:clay for sediment cores partitioned to 2 cm sections.

Sample ID	Sediment depth	Percent gr:sa:si:cl
Tennessee River Mile 547.5, Soft Mud Site		
133701	0-2	0:2:26:72
133702	2-4	0:2:23:75
133703	4-6	0:2:21:77
133704	6-8	0:2:19:79
133705	8-10	0:1:18:81
133706	10-12	0:2:20:78
133707	12-14	0:2:20:78
133708	14-16	0:2:21:77
133709	16-18	0:1:22:77
133710	18-20	0:1:28:71
133711	20-22	0:1:19:80
133712	22-24	0:2:23:75
133713	24-26	0:1:25:74
133714	26-28	0:2:18:80
133715	28-30	0:2:24:74
133716	30-32	0:1:27:72
133717	32-34	0:2:22:76
133718	34-36	0:2:26:72
133719	36-38	0:2:45:53
133720	38-40	0:2:32:66
133721	40-42	0:2:38:60
133722	42-44	0:2:36:62
133723	44-46	0:2:40:58

Sample ID, sediment depth, and percent gravel:sand:silt:clay for sediment cores partitioned to 2 cm sections.

Sample ID	Sediment depth	Percent gr:sa:si:cl
133724	46-48	0:1:37:62
133725	48-50	0:1:33:66
133726	50-52	0:2:37:61
133727	52-54	0:1:37:62
133728	54-56	0:1:29:70
133729	56-58	0:2:30:68
133730	58-60	0:2:29:69
133731	60-62	0:1:34:65
133732	62-64	0:1:38:61
133733	64-66	0:1:40:59
133734	66-68	0:2:35:63
133735	68-70	0:2:45:53
133736	70-72	0:2:35:63
Tennessee River Mile 550, Submerged Soil Site		
134601	0-2	0:2:48:50
134602	2-4	0:2:45:53
134603	4-6	0:2:45:53
134604	6-8	0:2:47:51
134605	8-10	0:3:50:47
134606	10-12	0:1:44:55
134607	12-14	0:2:45:53
134608	14-16	0:2:40:58
134609	16-18	0:1:39:60
134610	18-20	0:1:43:56

Sample ID, sediment depth, and percent gravel:sand:silt:clay for sediment cores partitioned to 2 cm sections.

Sample ID	Sediment depth	Percent gr:sa:si:cl
134611	20-22	0:3:39:58
134612	22-24	0:1:38:61
134613	24-26	0:3:39:58
134614	26-28	0:2:36:62
134615	28-30	0:3:40:57
134616	30-32	0:2:35:63
134617	32-34	0:3:38:59
134618	34-36	0:4:44:52
134619	36-39	0:9:50:41
Tennessee River Mile 538.9, Cohesive Mud Site		
135601	0-2	2:13:55:30
135602	2-4	1:14:57:28
135603	4-6	1:14:57:28
135604	6-8	1:11:47:41
135605	8-10	0:9:31:60
135606	10-12	0:10:36:54
135607	12-14	0:10:36:54
135608	14-16	0:4:39:57
135609	16-18	0:2:46:52
135610	18-20	0:2:42:56
135611	20-22	0:2:41:57
135612	22-24	0:2:42:56
135613	24-26	0:2:39:59
135614	26-28	0:2:48:50

Sample ID, sediment depth, and percent gravel:sand:silt:clay for sediment cores partitioned to 2 cm sections.

Sample ID	Sediment depth	Percent gr:sa:si:cl
135615	28-30	0:2:46:52
135616	30-32	0:1:48:51
135617	32-34	0:2:49:49
135618	34-36	0:7:54:39
135619	36-38	0:5:45:50
135620	38-40	0:12:49:39
135621	40-42	0:15:45:40
Tennessee River Mile 538, Sand and Gravel Site		
135901	0-2	0:83:12:5
135902	2-4	0:81:14:5
135903	4-6	0:81:14:5
135904	6-8	0:80:15:5
135905	8-10	0:81:15:4
135906	10-12	0:82:12:6
135907	12-14	0:89:6:5
Tennessee River Mile 534.4, Sandy Mud Site		
136301	0-2	0:17:53:30
136302	2-4	0:18:55:27
136303	4-6	0:20:53:27
136304	6-9	0:34:49:17

APPENDIX 4

^{137}Cs Activities for Sediment Core Samples

APPENDIX 5

Critical Shear Stress Data

EROSION TESTING RESULTS

SAMPLE #	EROSION RATE / SHEAR STRESS	CRITICAL SHEAR STRESS	COMMENTS
132200	0.00051	9	
132300	0.00067	7	
132600	0.000067	52	
133000	***	***	FELL APART TOO FAST, NO DATA
133400	0.0012	12	
133800	0.00017	30	
134000	0.00021	68	
134300	0.000078	30	
135100	0.00231	30	
135300	0.00012	48	
136100	0	<15	FELL APART TOO FAST, INCOMPLETE DATA
136500	0.0004	28	
137100	0.000027	1	FELL APART TOO FAST, INCOMPLETE DATA
134800	***	***	COULD NOT TEST
135700	***	***	COULD NOT TEST
136800	***	***	COULD NOT TEST

EROSION TEST CALCULATIONS

DATE = 6/30/93

SAMPLE # = 132200
SAMPLE HEIGHT (cm) = 4.79
SAMPLE DIAM (cm) = 7.62

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	SAMPLE WEIGHTS FINAL (grams)	SAMPLE WEIGHTS LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
4a	1	0.960	743.7	743.7	0.0	0.000000	1	0.000000	2.156165		
4b	1	0.960	743.7	743.5	0.2	0.001745	1	0.001745	2.156165	0.00087	2.15617
5a	6	2.891	743.5	743.5	0.0	0.000000	1	0.000000	6.495791	0.00000	6.49579
6a	8	3.664	743.5	743.5	0.0	0.000000	1	0.000000	8.231642	0.00000	8.23164
7a	13	5.596	743.5	743.4	0.1	0.000873	1	0.000873	12.571268		
7b	14	5.982	743.4	741.1	2.3	0.020068	1	0.020068	13.439194		
7c	14	5.982	741.1	740.7	0.4	0.003490	1	0.003490	13.439194		
7d	15	6.368	740.7	740.0	0.7	0.006108	1	0.006108	14.307119	0.00763	13.43919
8a	22	9.073	740.0	737.3	2.7	0.023558	2	0.011779	20.382596		
8b	23	9.459	737.3	736.7	0.6	0.005235	1	0.005235	21.250521		
8c	23	9.459	736.7	735.7	1.0	0.008725	1	0.008725	21.250521	0.00858	20.96121
9a	28	11.391	735.7	734.5	1.2	0.010470	1	0.010470	25.590147		
9b	36	14.481	733.2	729.1	4.1	0.035774	1	0.035774	32.533550		
9c	25	10.232	729.1	728.7	0.4	0.003490	1	0.003490	22.986372	0.01658	27.03669
10a	47	18.731	728.7	726.9	1.8	0.015706	1	0.015706	42.080728		
10b	49	19.504	726.9	723.4	3.5	0.030539	1	0.030539	43.816578	0.02312	42.94865

DATE = 7/26/93

EROSION TEST CALCULATIONS

SAMPLE # = 132300
SAMPLE HEIGHT (cm) = 7.62
SAMPLE DIAM (cm) = 7.62

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	SAMPLE WEIGHTS FINAL (grams)	SAMPLE WEIGHTS LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	10	4.614	954.6	954.6	0.0	0.000000	1	0.000000	6.516537	0.000000	6.516537
2a	15	6.546	954.6	953.0	1.6	0.008776	1	0.008776	9.244465	0.007130	9.244465
2b	15	6.546	953.0	952.0	1.0	0.005485	1	0.005485	9.244465		
3a	22	9.250	952.0	949.3	2.7	0.014809	1	0.014809	13.063564	0.011518	13.063564
3b	22	9.250	949.3	947.8	1.5	0.008227	1	0.008227	13.063564		
4a	28	11.568	947.8	945.5	2.3	0.012615	1	0.012615	16.337077	0.011792	16.337077
4b	28	11.568	945.5	943.5	2.0	0.010970	1	0.010970	16.337077		
5a	5	2.683	943.5	943.5	0.0	0.000000	1	0.000000	3.788609	0.000000	3.788609
6a	11	5.001	943.5	943.5	0.0	0.000000	1	0.000000	7.062122	0.000000	7.062122

EROSION TEST CALCULATIONS

DATE = 7/18/93

SAMPLE # = 132600
SAMPLE HEIGHT (cm) = 7.36
SAMPLE DIAM (cm) = 7.11

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	FINAL (grams)	LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
9a	55	21.822	922.1	922.0	0.1	0.000609	1	0.000609	36.646992	0.00061	36.64699
10a	65	25.685	922.0	921.8	0.2	0.001217	1	0.001217	43.134991	0.00122	43.13499
11a	77	30.321	921.8	921.8	0.0	0.000000	1	0.000000	50.920590	0.00000	50.92059
12a	100	39.206	921.8	921.2	0.6	0.003652	1	0.003652	65.842987		
12b	98	38.434	921.2	920.9	0.3	0.001826	1	0.001826	64.545388	0.00274	65.19419
13a	120	46.933	920.9	920.3	0.6	0.003652	1	0.003652	78.818985	0.00365	78.81899

EROSION TEST CALCULATIONS

DATE = 7/5/93

SAMPLE # = 133400
SAMPLE HEIGHT (cm) = 7.62
SAMPLE DIAM (cm) = 7.37

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	SAMPLE WEIGHTS FINAL (grams)	SAMPLE WEIGHTS LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	0	0.573	944.9	944.9	0.0	0.000000	1	0.000000	0.865670	0.00000	0.86567
1b	0	0.573	944.9	944.9	0.0	0.000000	1	0.000000	0.865670		
3a	8	3.664	946.0	946.0	0.0	0.000000	1	0.000000	5.531488	0.00000	6.11472
3b	10	4.437	946.1	946.1	0.0	0.000000	1	0.000000	6.697943		
4a	12	5.209	946.1	946.1	0.0	0.000000	1	0.000000	7.864397	0.00000	11.70334
5a	18	7.527	946.1	945.7	0.4	0.002268	1	0.002268	11.363761	0.00113	12.23860
5b	21	8.686	945.7	945.7	0.0	0.000000	1	0.000000	13.113443		
6b	30	12.163	940.5	939.2	1.3	0.007372	1	0.007372	18.362489	0.00662	23.02831
6c	43	17.186	939.2	938.0	1.2	0.006805	1	0.006805	25.944444		
6d	41	16.413	938.0	937.0	1.0	0.005671	1	0.005671	24.777989		
7a	50	19.890	937.0	933.4	3.6	0.020415	1	0.020415	30.027035	0.02325	30.61026
7b	52	20.663	933.4	928.8	4.6	0.026086	1	0.026086	31.193489		

EROSION TEST CALCULATIONS

DATE = 7/22/93

SAMPLE # = 133800
SAMPLE HEIGHT (cm) = 7.62
SAMPLE DIAM (cm) = 7.37

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	FINAL (grams)	LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	35	14.095	883.7	883.7	0.0	0.000000	1	0.000000	21.278625	0.000000	21.278625
2a	47	18.731	883.7	883.9	-0.2	-0.001134	1	-0.001134	28.277353	-0.001134	28.277353
3a	71	28.003	883.9	883.1	0.8	0.004537	1	0.004537	42.274808	0.003970	39.358671
3b	61	24.140	883.1	882.5	0.6	0.003403	1	0.003403	36.442535		
4a	90	35.343	882.5	881.5	1.0	0.005671	1	0.005671	53.356126	0.004537	50.439990
4b	80	31.480	881.5	880.9	0.6	0.003403	1	0.003403	47.523853		
6a	99	38.820	874.0	872.7	1.3	0.007372	1	0.007372	58.605172	0.007372	58.605172

EROSION TEST CALCULATIONS

DATE = 7/23/93

SAMPLE # = 134000
SAMPLE HEIGHT (cm) = 7.62
SAMPLE DIAM (cm) = 7.37

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	FINAL (grams)	LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	35	14.273	854.4	854.2	0.2	0.001134	1	0.001134	21.546816	0.001418	22.713271
1b	39	15.818	854.2	853.9	0.3	0.001701	1	0.001701	23.879726		
2a	37	15.045	853.9	854.0	-0.1	-0.000567	1	-0.000567	22.713271	-0.000567	22.713271
3a	80	31.657	853.9	854.0	-0.1	-0.000567	1	-0.000567	47.792045	0.000000	47.792045
4a	93	36.680	854.0	853.7	0.3	0.001701	1	0.001701	55.374000	0.000000	55.957227
4b	95	37.452	853.7	853.6	0.1	0.000567	1	0.000567	56.540454		
5a	110	43.247	853.6	853.4	0.2	0.001134	1	0.001134	65.288864	0.000000	65.288864
7a	117	45.952	851.5	851.0	0.5	0.002835	1	0.002835	69.371455	0.002835	69.371455
8a	130	50.974	851.0	850.5	0.5	0.002835	1	0.002835	76.953410	0.002835	76.953410
9a	155	60.632	850.5	850.0	0.5	0.002835	1	0.002835	91.534092	0.002835	91.534092
10a	170	66.427	850.0	848.4	1.6	0.009073	1	0.009073	100.282501	0.007656	100.282501
10b	170	66.427	848.4	847.3	1.1	0.006238	1	0.006238	100.282501		
11a	185	72.222	847.3	844.9	2.4	0.013610	1	0.013610	109.030911	0.011342	109.030911
11b	185	72.222	844.9	843.3	1.6	0.009073	1	0.009073	109.030911		

EROSION TEST CALCULATIONS

DATE = 7/24/93

SAMPLE # = 134300
SAMPLE HEIGHT (cm) = 7.62
SAMPLE DIAM (cm) = 7.37

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	FINAL (grams)	LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	47	18.909	873.4	873.1	0.3	0.001701	1	0.001701	28.545544	0.001134	28.837158
1b	48	19.295	873.1	873.0	0.1	0.000567	1	0.000567	29.128771		
2a	68	27.022	873.0	872.3	0.7	0.003970	1	0.003970	40.793317	0.003403	40.501704
2b	67	26.635	872.3	871.8	0.5	0.002835	1	0.002835	40.210090		
3a	100	39.384	871.8	871.0	0.8	0.004537	1	0.004537	59.456591	0.005104	62.372727
3b	110	43.247	871.0	870.0	1.0	0.005671	1	0.005671	65.288864		

EROSION TEST CALCULATIONS

DATE = 7/24/93

SAMPLE # = 135100
SAMPLE HEIGHT (cm) = 6.60
SAMPLE DIAM (cm) = 7.37

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	FINAL (grams)	LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
2a	32	13.114	788.7	788.3	0.4	0.002619	1	0.002619	22.856692		
2b	32	13.114	788.3	788.1	0.2	0.001309	1	0.001309	22.856692	0.001964	22.856692
3a	26	10.796	788.1	788.1	0.0	0.000000	1	0.000000	18.816517	0.000000	16.297771
4a	55	21.999	788.1	781.9	6.2	0.040593	1	0.040593	38.344027		
4b	53	21.227	781.9	779.3	2.6	0.017023	1	0.017023	36.997303	0.028808	37.670665
5a	70	27.794	779.3	771.0	8.3	0.054342	1	0.054342	48.444464		
5b	74	29.339	771.0	759.5	11.5	0.075293	1	0.075293	51.137913	0.064818	49.791189

EROSION TEST CALCULATIONS

DATE = 7/25/93

SAMPLE # = 135300
SAMPLE HEIGHT (cm) = 7.11
SAMPLE DIAM (cm) = 7.37

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	FINAL (grams)	LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	4	2.296	834.4	834.2	0.2	0.001216	1	0.001216	3.715441	0.001216	3.715441
2a	20	8.478	832.0	832.0	0.0	0.000000	1	0.000000	13.716436	0.000000	13.716436
3a	25	10.409	832.0	831.8	0.2	0.001216	1	0.001216	16.841747	0.001216	16.841747
4a	52	20.840	831.8	831.9	-0.1	-0.000608	1	-0.000608	33.718425	-0.000608	33.718425
5a	69	27.408	831.9	831.9	0.0	0.000000	1	0.000000	44.344482	0.000000	44.344482
6a	95	37.452	831.9	831.6	0.3	0.001823	1	0.001823	60.596099	0.001823	60.596099
7a	135	52.906	831.6	830.9	0.7	0.004254	1.25	0.003403	85.598585	0.003829	85.598585
7b	135	52.906	830.9	830.2	0.7	0.004254	1	0.004254	85.598585		
8b	160	62.564	820.5	819.2	1.3	0.007901	1	0.007901	101.225139	0.006989	101.225139
8c	160	62.564	819.2	818.2	1.0	0.006078	1	0.006078	101.225139		

EROSION TEST CALCULATIONS

DATE = 7/25/93

SAMPLE # = 136100
SAMPLE HEIGHT (cm) = 6.10
SAMPLE DIAM (cm) = 6.86

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	SAMPLE WEIGHTS FINAL (grams)	SAMPLE WEIGHTS LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	18	7.705	795.6	793.5	2.1	0.015982	1	0.015982	16.771214		
1b	18	7.705	793.5	780.5	13.0	0.098937	1	0.098937	16.771214	0.057460	16.771214
2a	17	7.319	780.0	778.6	1.4	0.010655	1	0.010655	15.930303		
2b	17	7.319	778.6	764.6	14.0	0.106548	1	0.106548	15.930303	0.058601	15.930303

EROSION TEST CALCULATIONS

DATE = 7/25/93

SAMPLE # = 136500
SAMPLE HEIGHT (cm) = 7.11
SAMPLE DIAMETER (cn 7.11

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	FINAL (grams)	LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	12	5.387	915.9	915.6	0.3	0.001890	1	0.001890	9.365047	0.001102	9.365047
1c	12	5.387	911.1	911.0	0.1	0.000630	2	0.000315	9.365047		
2a	12	5.387	911.0	911.0	0.0	0.000000	4	0.000000	9.365047	0.000000	9.365047
3a	25	10.409	911.0	911.1	-0.1	-0.000630	6	-0.000105	18.096014	-0.000105	18.096014
4a	51	20.454	911.1	908.5	2.6	0.016380	8	0.002047	35.557947	0.001339	32.199883
4b	41	16.591	908.5	907.6	0.9	0.005670	9	0.000630	28.841819		
5a	56	22.386	907.6	903.0	4.6	0.028979	11	0.002634	38.916011	0.005675	39.923431
5b	59	23.545	903.0	886.4	16.6	0.104578	12	0.008715	40.930850		
6a	74	29.339	886.4	866.3	20.1	0.126627	14	0.009045	51.005042	0.009045	51.005042

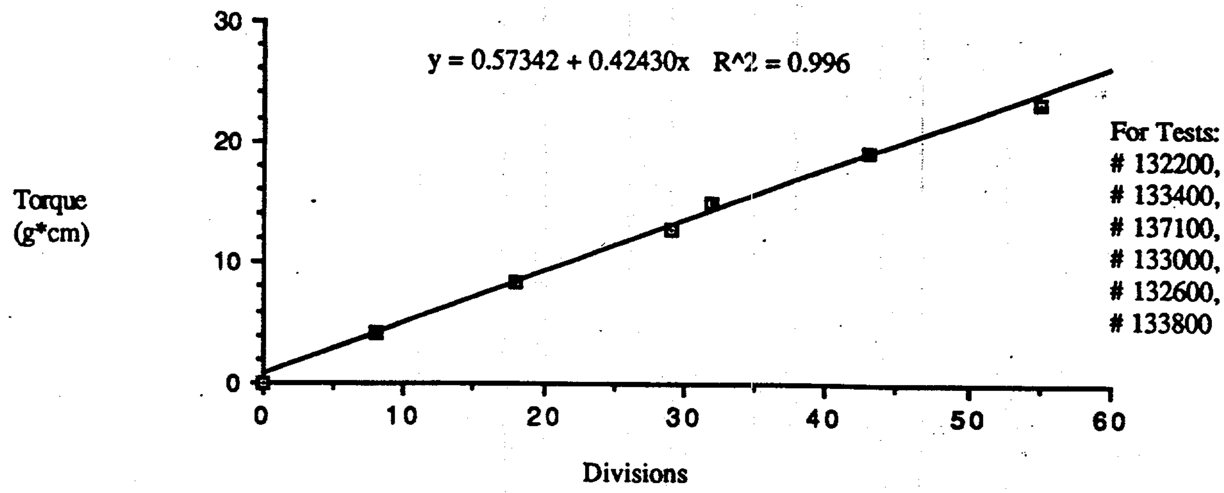
EROSION TEST CALCULATIONS

DATE = 7/8/93

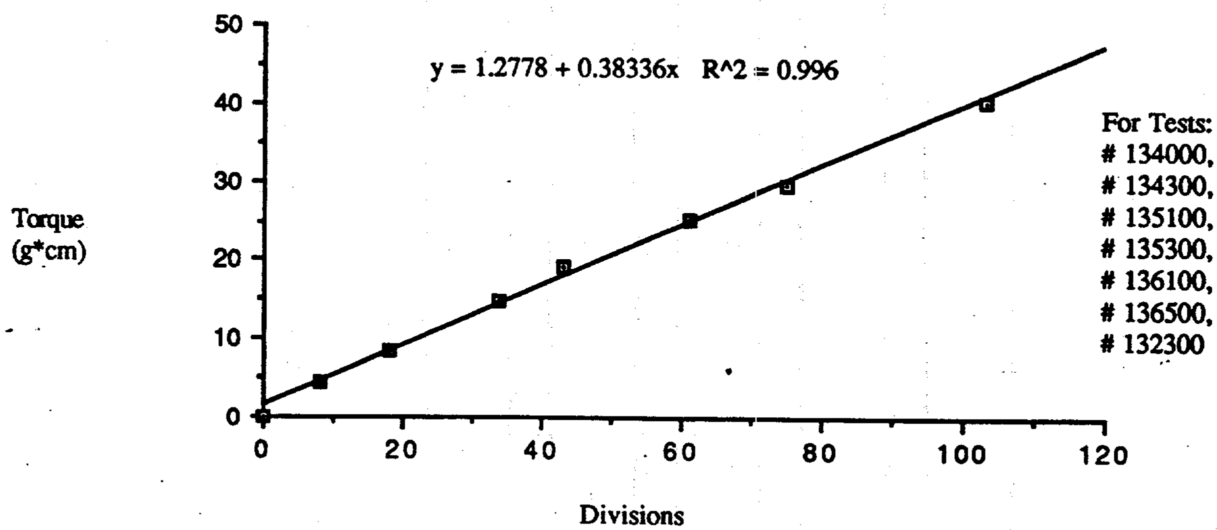
SAMPLE # = 137100
SAMPLE HEIGHT (cm) = 7.36
SAMPLE DIAM (cm) = 7.36

TRIAL	DIVISIONS MEASURED	TORQUE (g-cm)	SAMPLE WEIGHTS INITIAL (grams)	SAMPLE WEIGHTS FINAL (grams)	SAMPLE WEIGHTS LOSS (grams)	EROSION (g/cm^2)	TIME OF RUN (min)	EROSION RATE (g/cm^2*min)	SHEAR STRESS (dyne/cm^2)	AVG. EROSION RATE	AVG. SHEAR STRESS
1a	0	0.573	1028.0	1028.0	0.0	0.000000	1	0.000000	0.898688		
1b	0	0.573	1028.0	1028.0	0.0	0.000000	1	0.000000	0.898688	0	0.8986876
2a	0	0.573	1028.0	1027.4	0.6	0.003527	1	0.003527	0.898688		
2b	0	0.573	1027.4	1025.7	1.7	0.009995	1	0.009995	0.898688	0.006761	0.8986876
3a	5	2.505	1025.7	1023.0	2.7	0.015874	1	0.015874	3.926050		
3b	6	2.891	1023.0	1022.5	0.5	0.002940	1	0.002940	4.531522		
3c	7	3.278	1022.5	1022.2	0.3	0.001764	1	0.001764	5.136994	0.006859	4.53152196

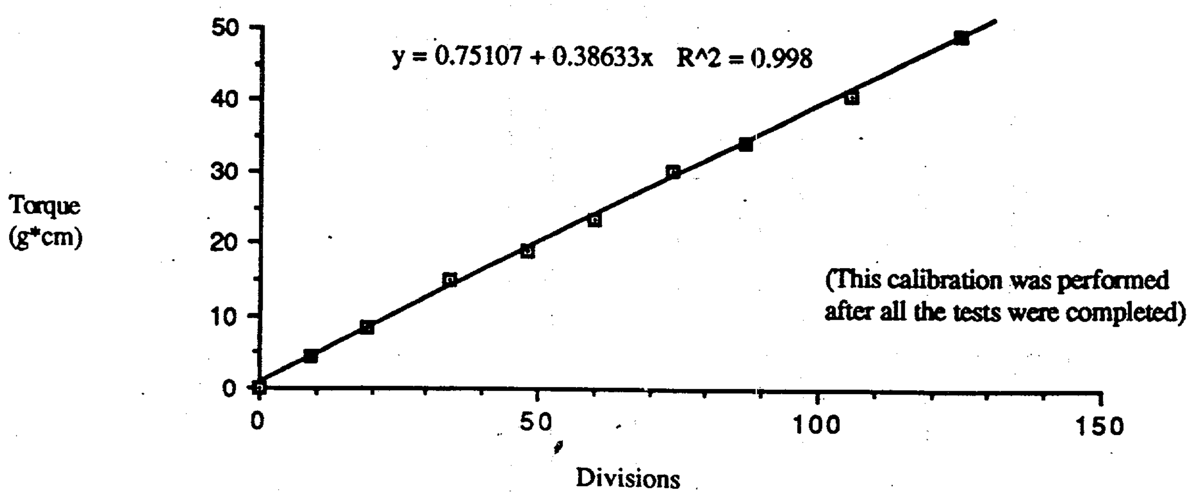
6/25/93 Calibration



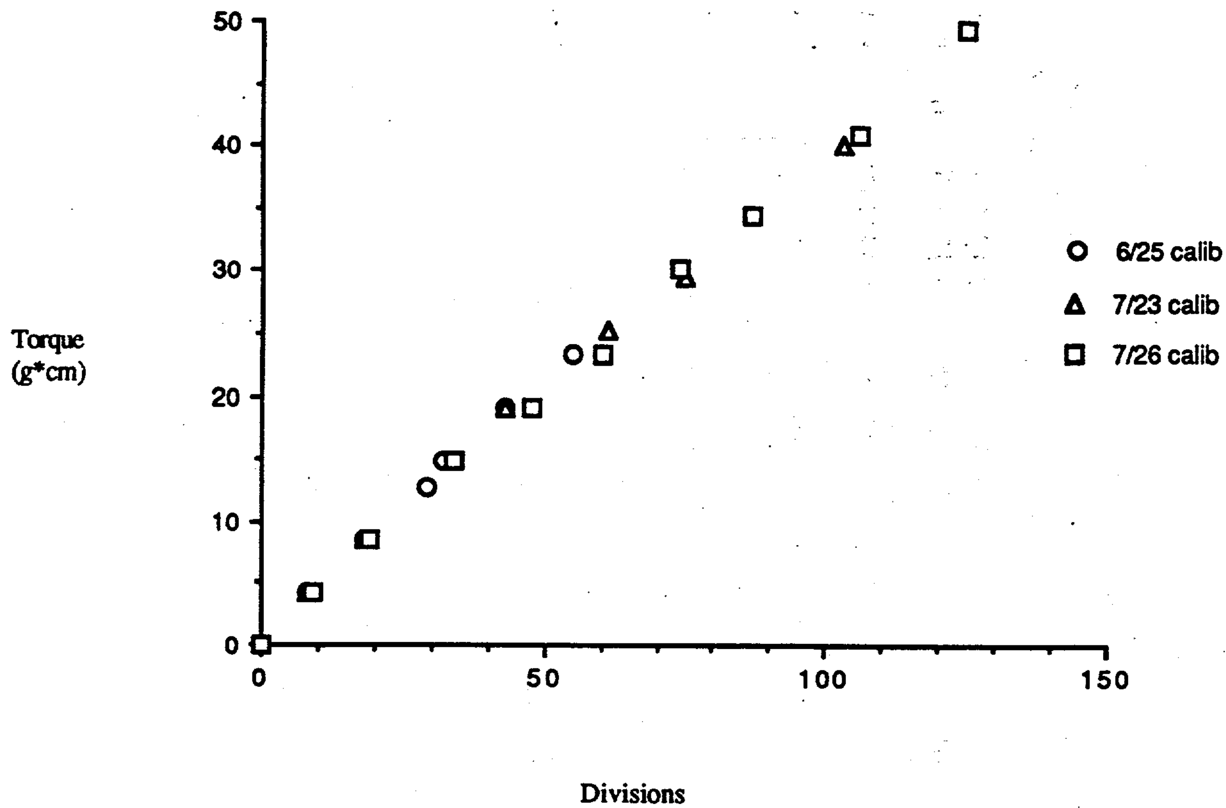
7/23/93 Calibration



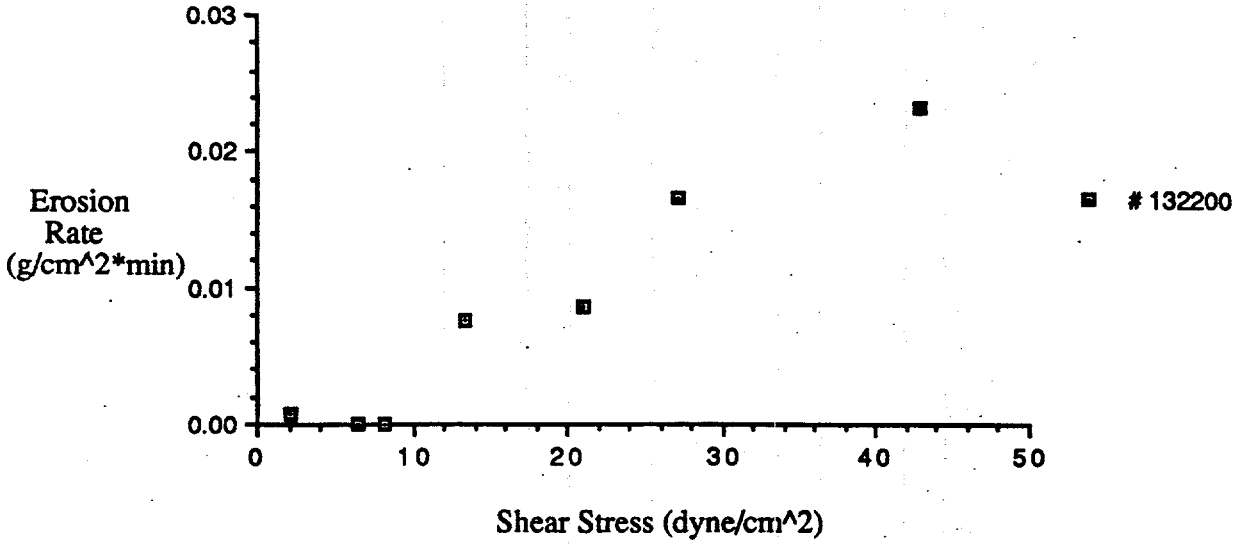
7/26/93 Calibration



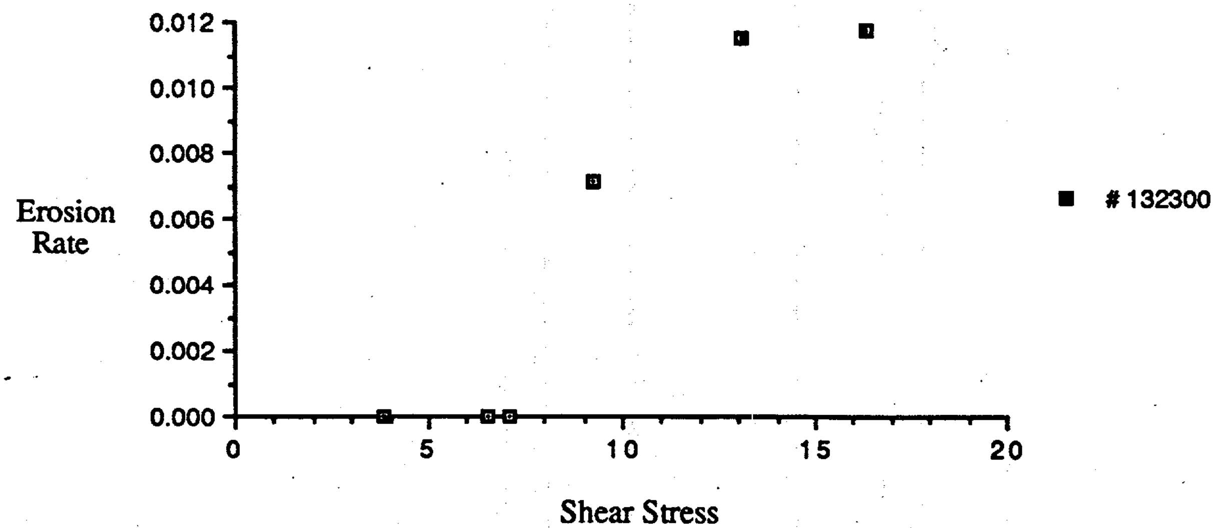
Comparison of Calibration Curves



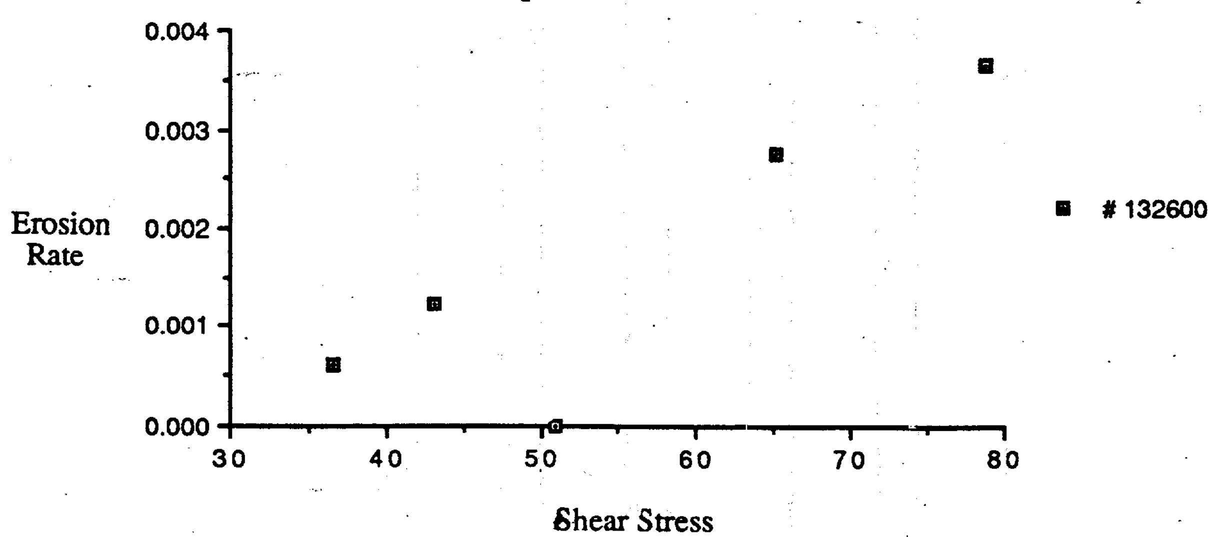
Sample # 132200

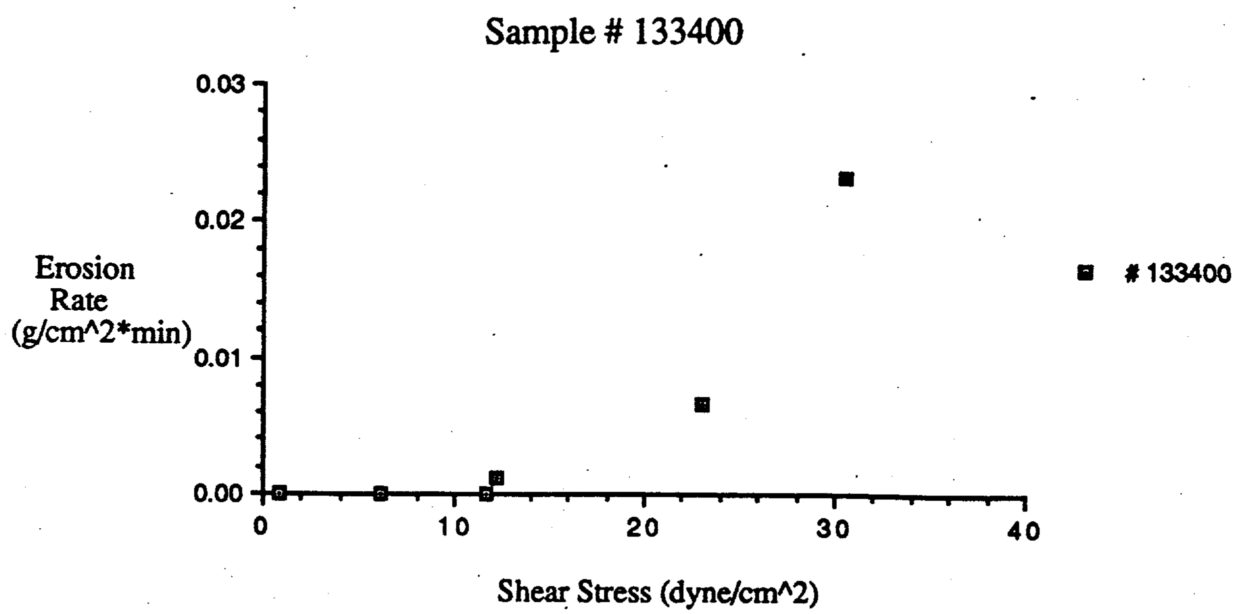


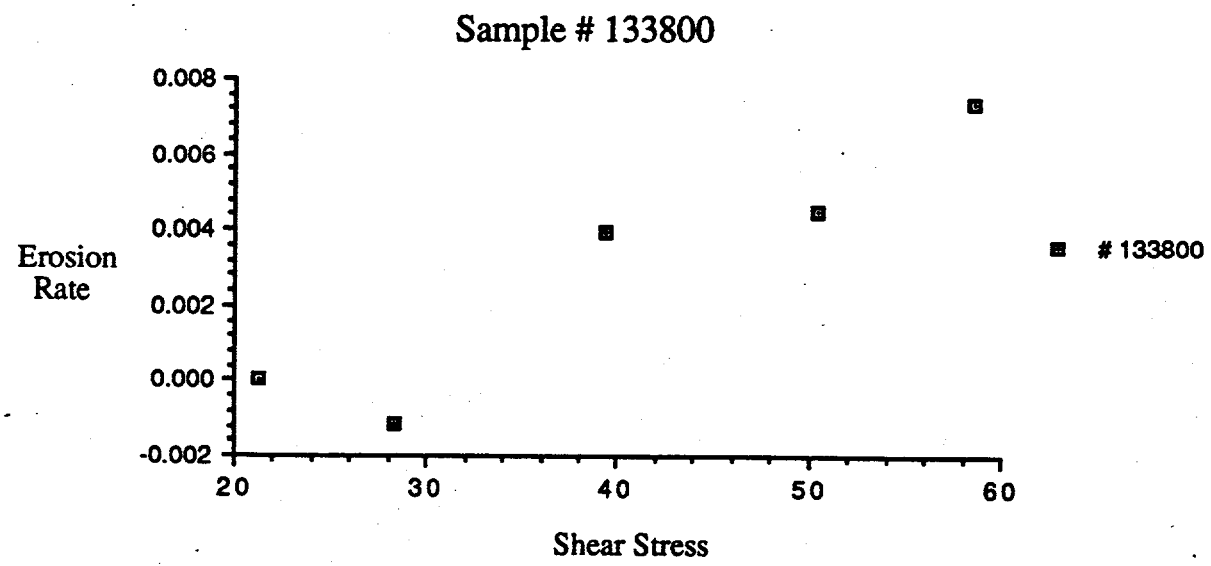
Sample # 132300

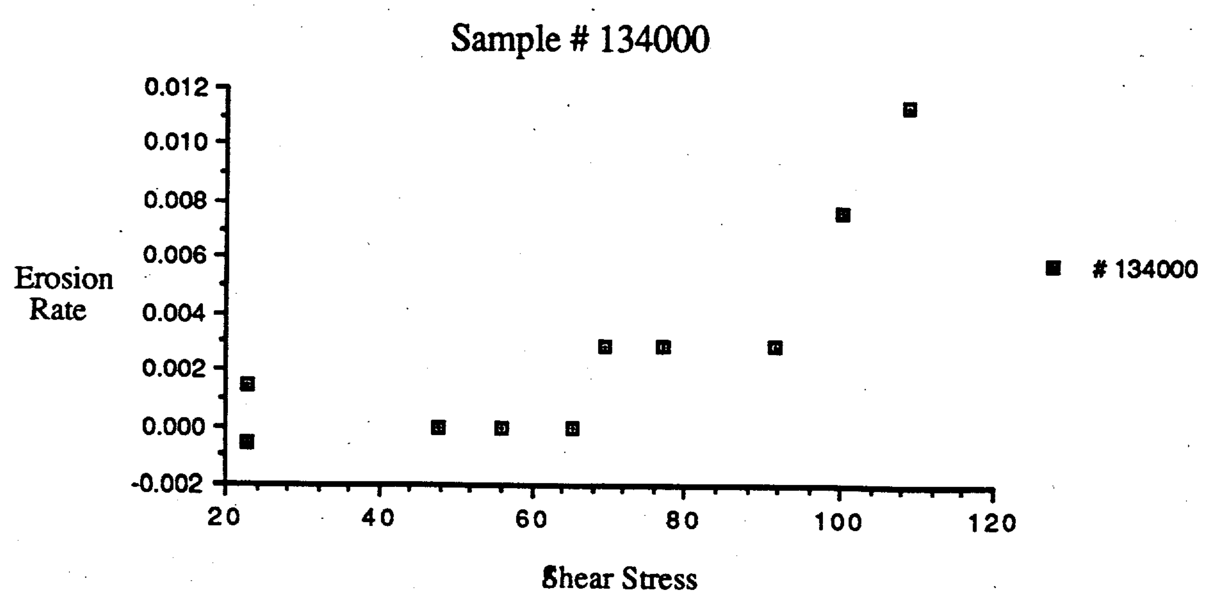


Sample # 132600

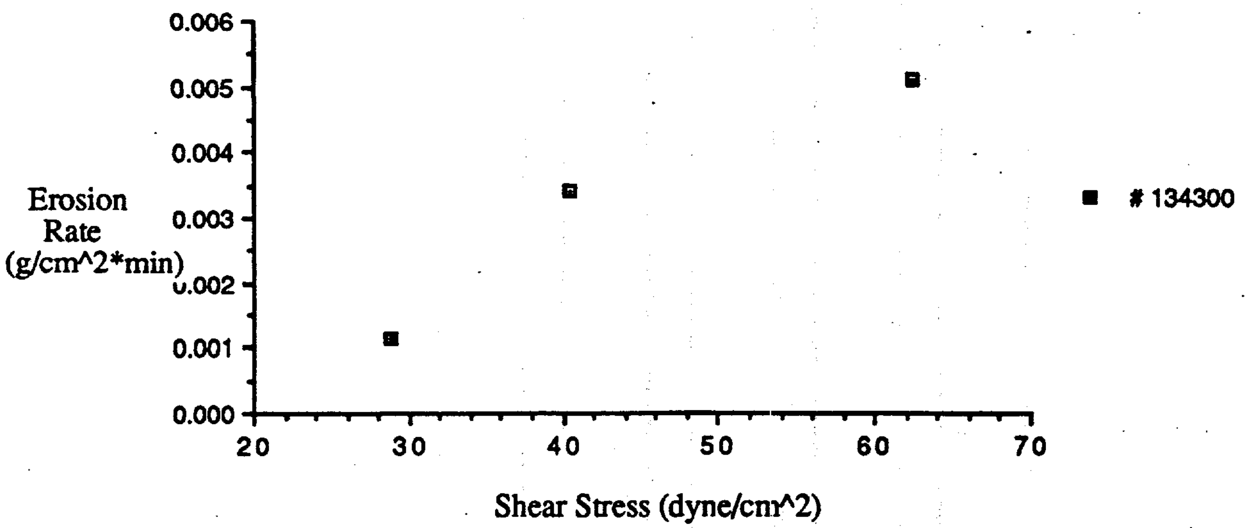



Sample # 133400
0.03
0.02
0.01
0.00
Erosion
Rate
(g/cm^2*min)
0
10
20
30
40
Shear Stress (dyne/cm^2)
133400

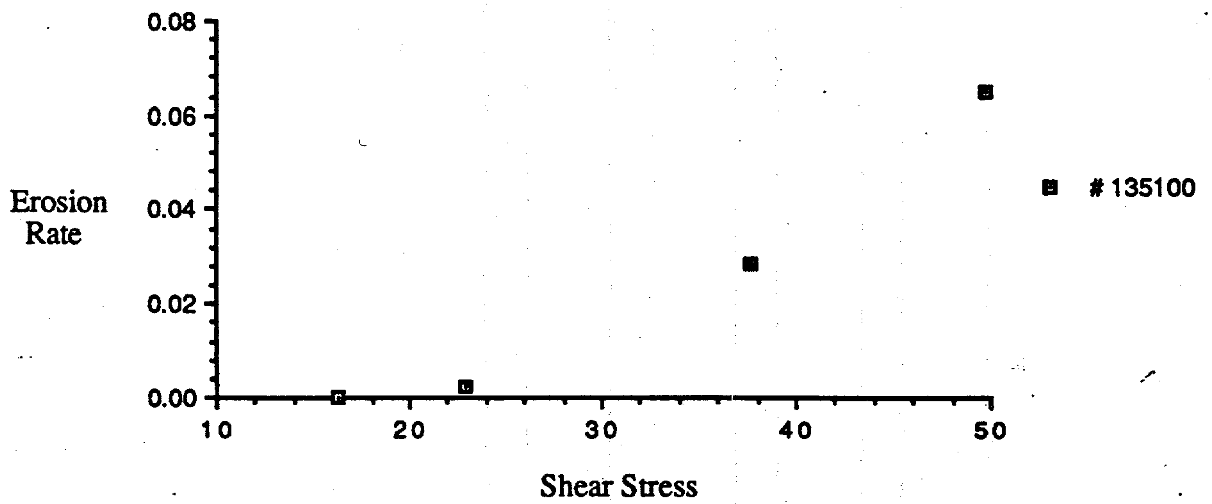

Sample # 133800
0.008
0.006
0.004
0.002
0.000
-0.002
Erosion
Rate
20
30
40
50
60
Shear Stress
133800


Sample # 134000
0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
Erosion
Rate
20
40
60
80
100
120
Shear Stress
134000

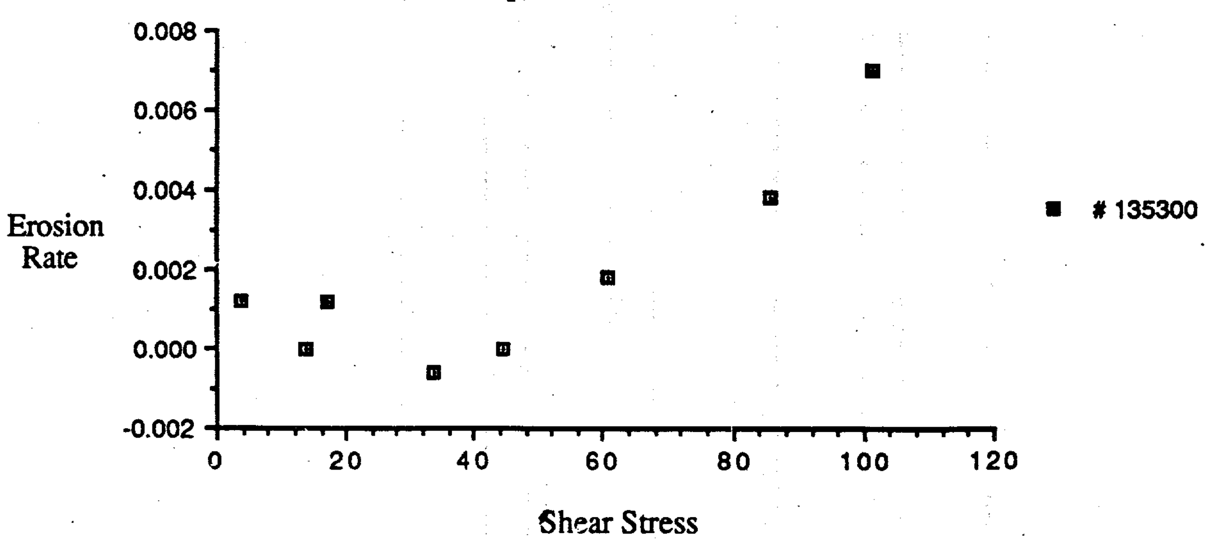
Sample # 134300

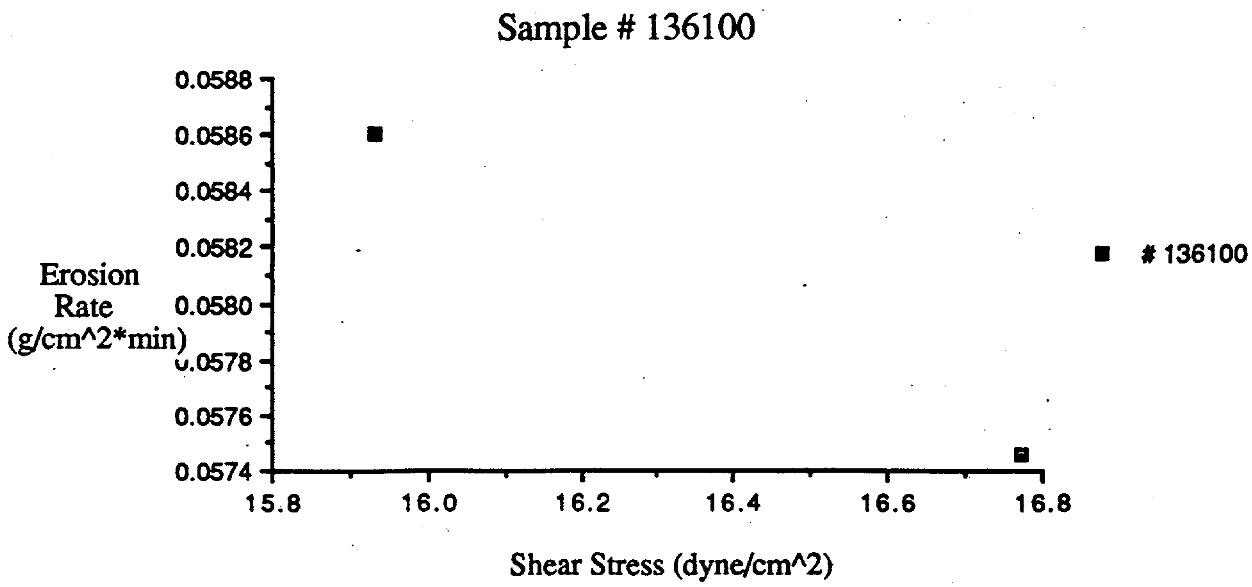


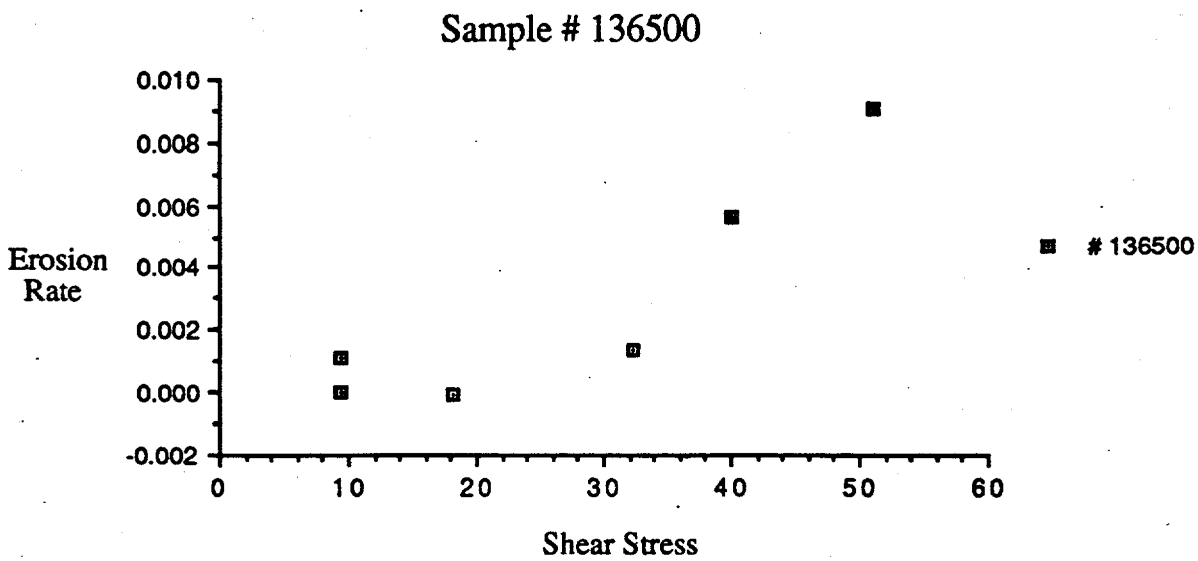
Sample # 135100

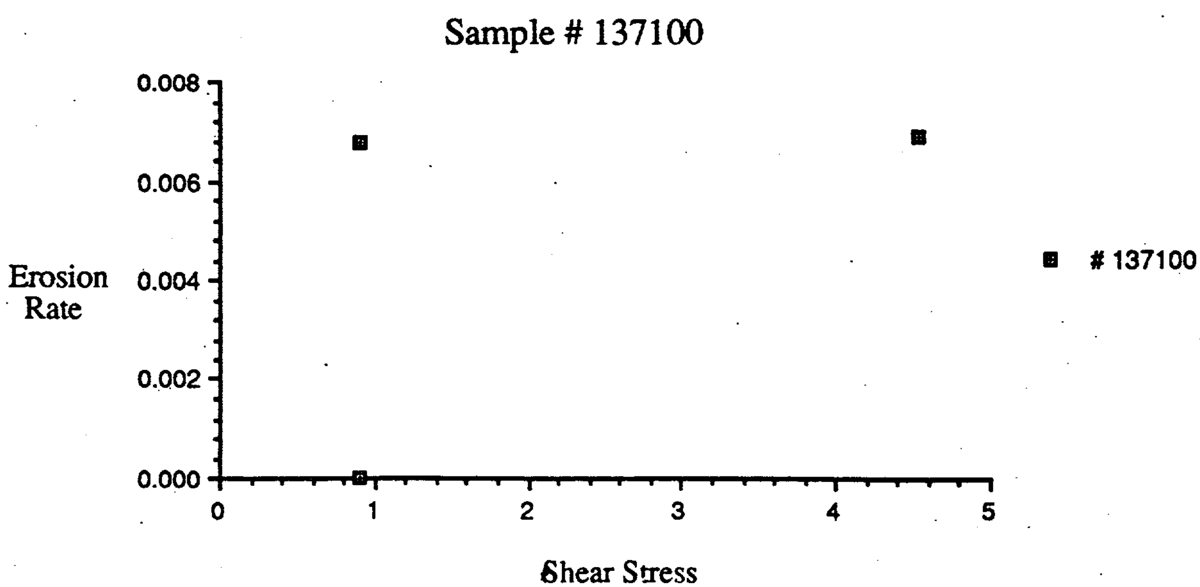


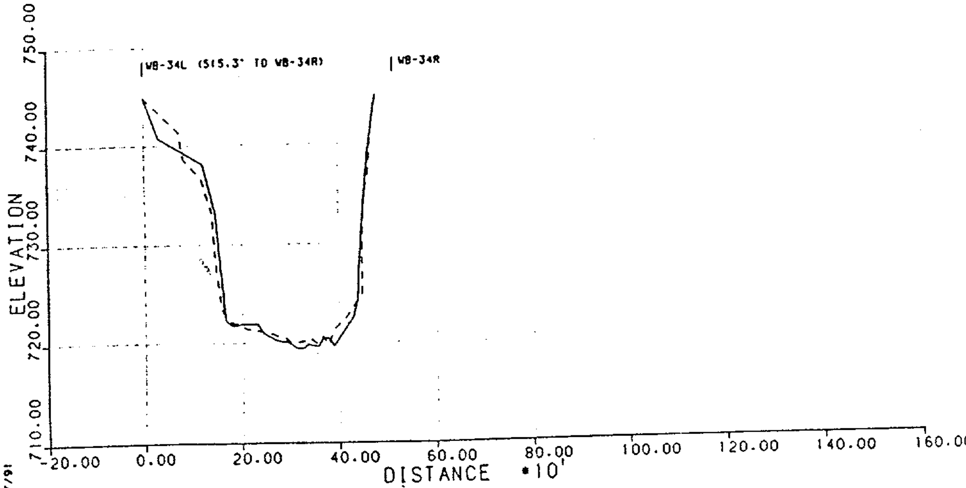
Sample # 135300




Sample # 136100
Erosion Rate (g/cm^2*min)
0.0588
0.0586
0.0584
0.0582
0.0580
0.0578
0.0576
0.0574
15.8
16.0
16.2
16.4
16.6
16.8
Shear Stress (dyne/cm^2)
136100

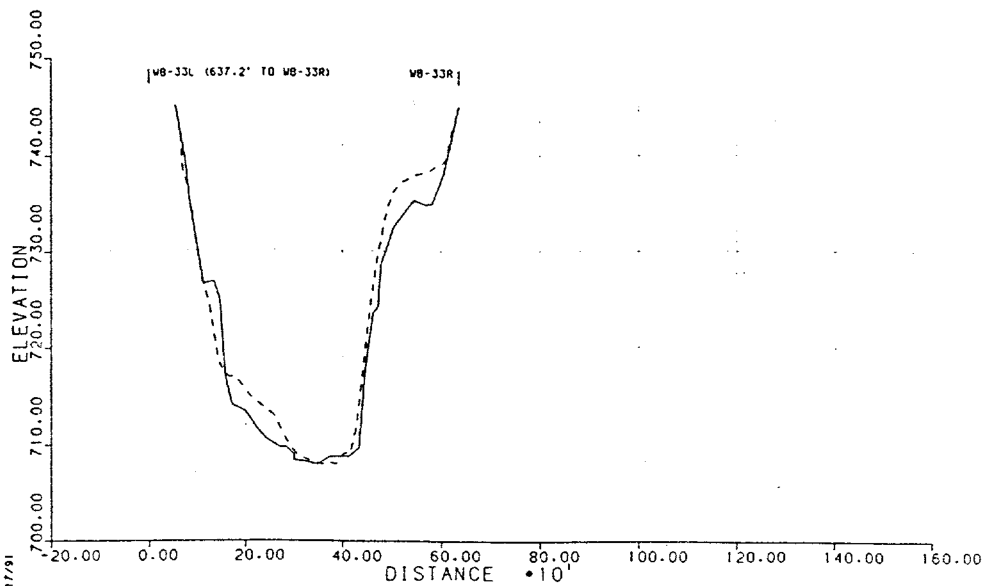

Sample # 136500
Erosion Rate
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
0
10
20
30
40
50
60
Shear Stress
136500


Sample # 137100
Erosion Rate
0.008
0.006
0.004
0.002
0.000
0
1
2
3
4
5
Shear Stress
137100



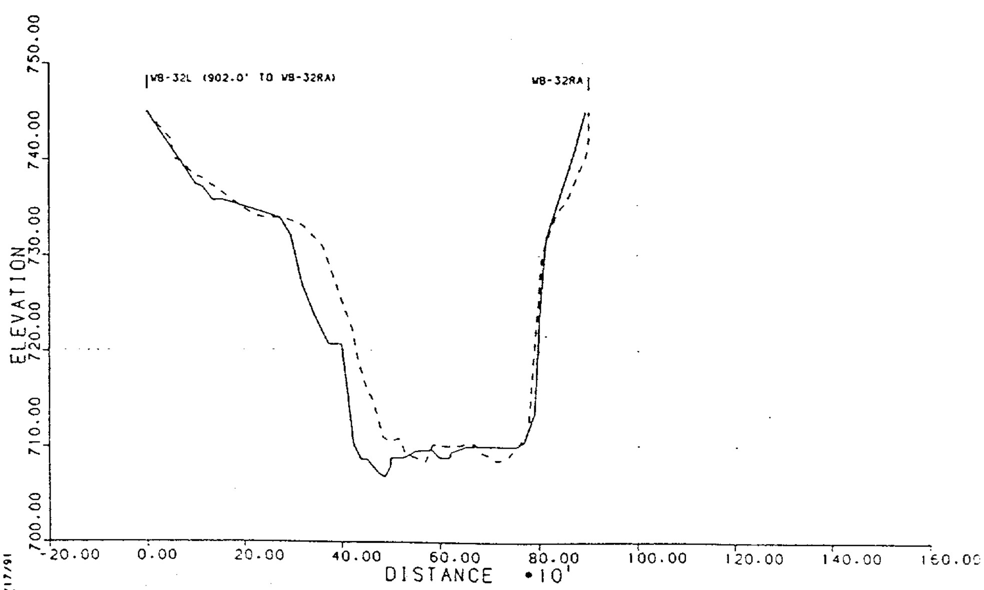
10/17/91 DLS

WATTS BAR RESERVOIR CLINCH RIVER MI. 19.2 SEDIMENT RANGE #34
——OCT 1946 ----JUNE 1991



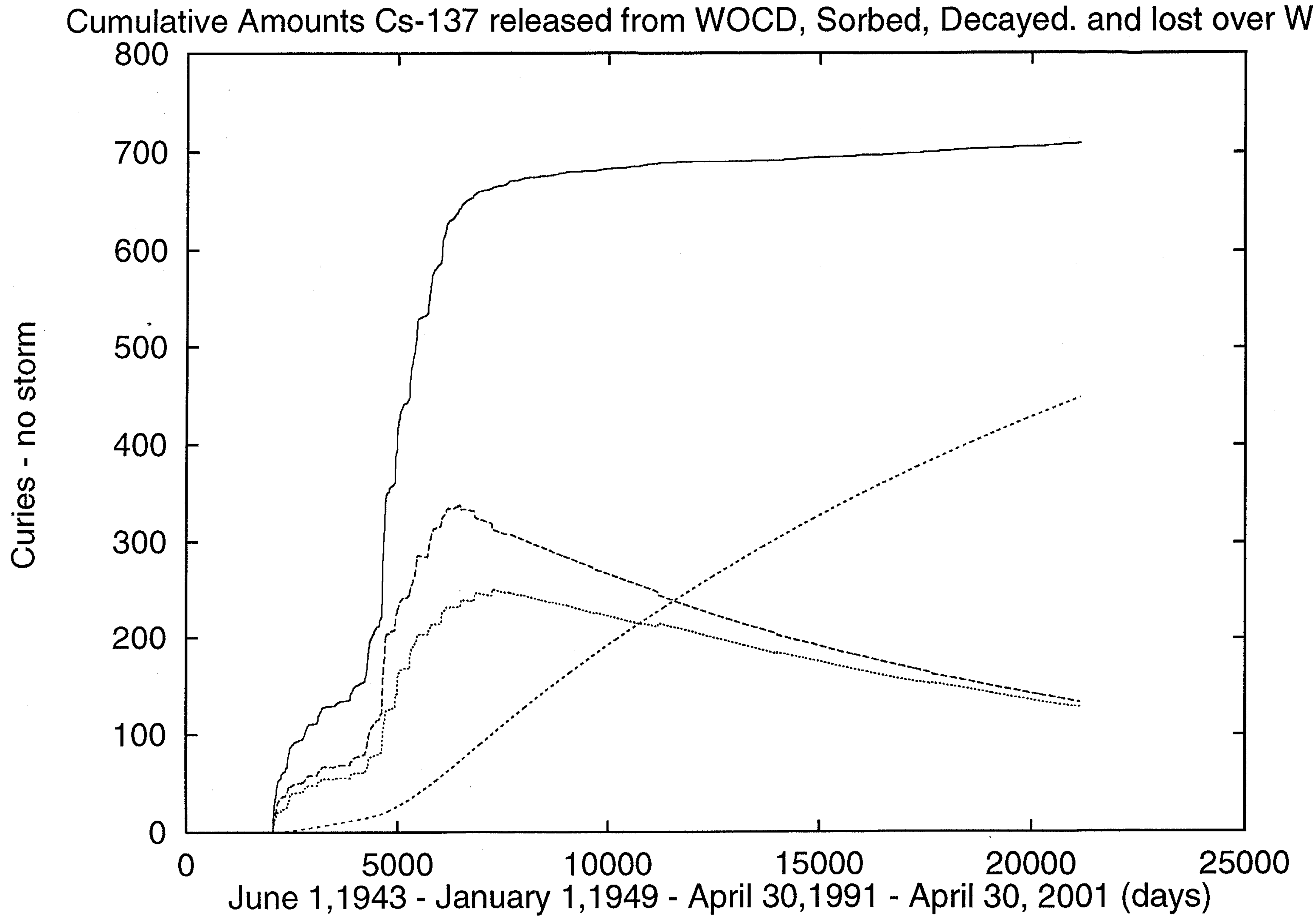
10/17/91 JMF

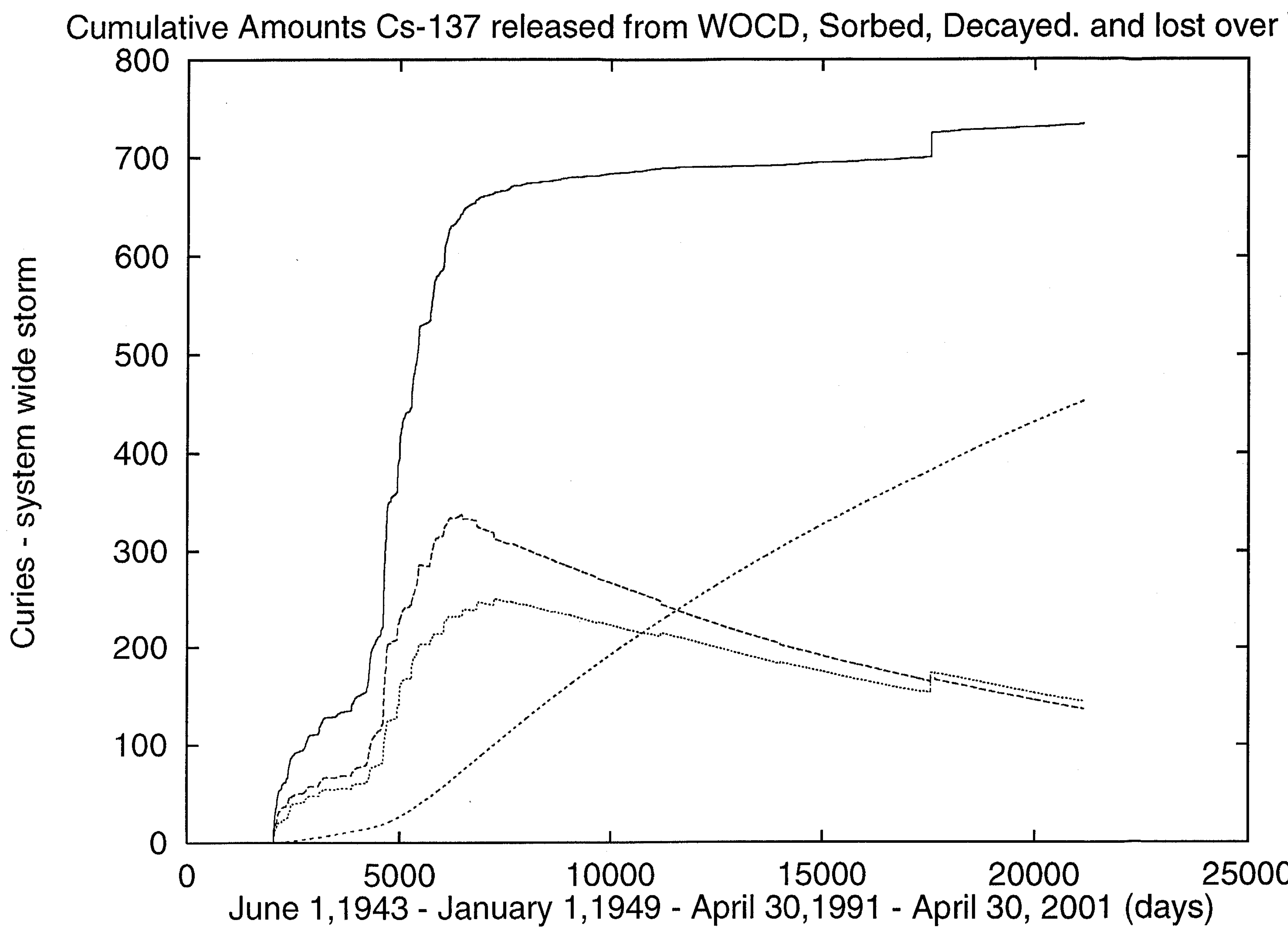
WATTS BAR RESERVOIR CLINCH RIVER MI. 11.8 SEDIMENT RANGE #33
——OCT 1946 ----JUNE 1991



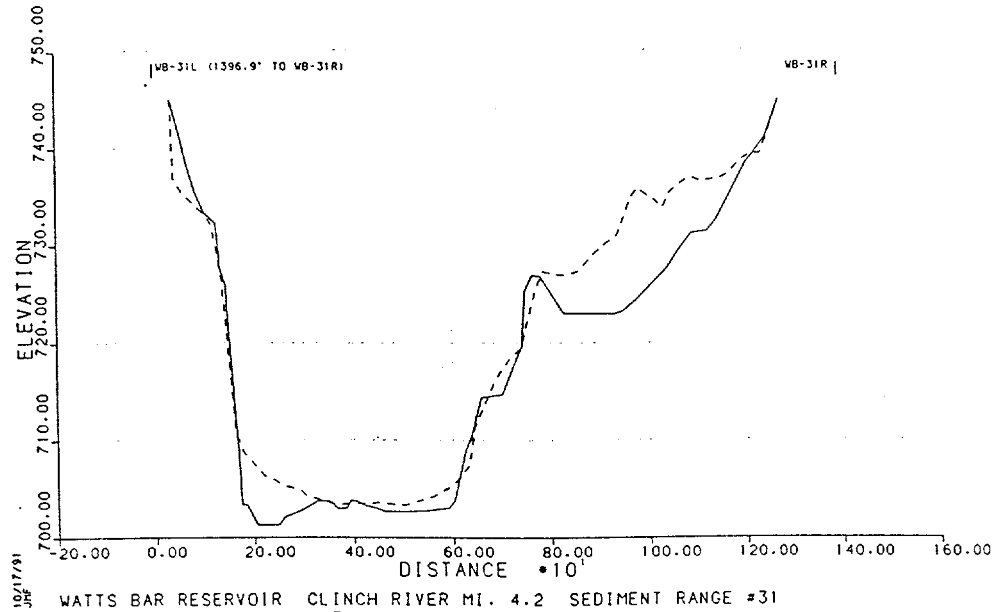
10/17/91 JMF

WATTS BAR RESERVOIR CLINCH RIVER MI. 7.6 SEDIMENT RANGE #32
——OCT 1946 ----JUNE 1991

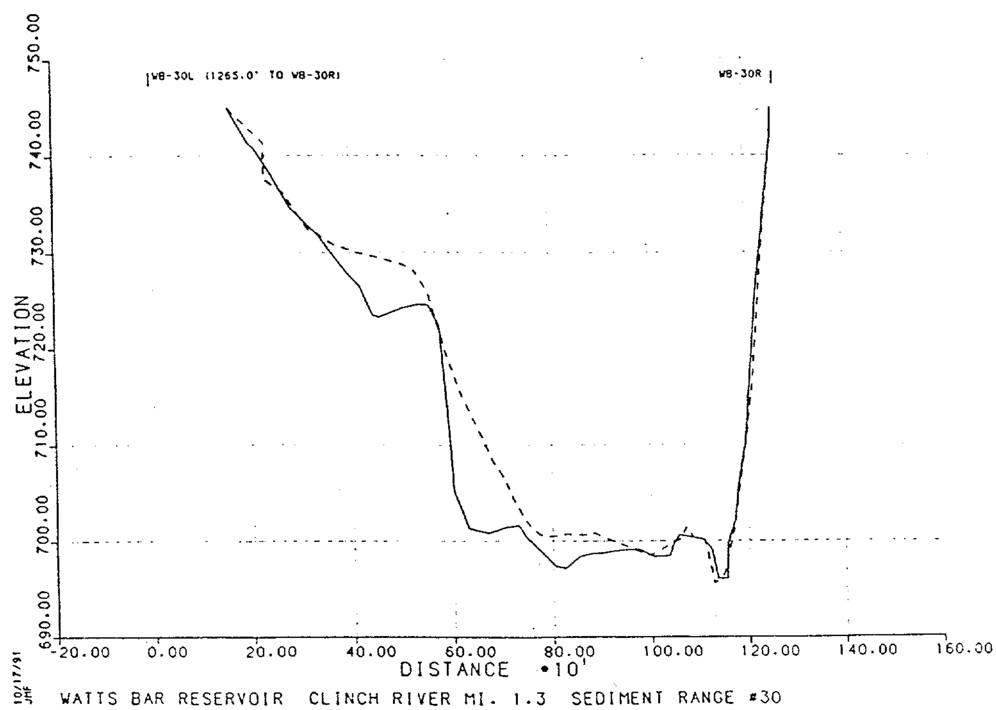

Cumulative Amounts Cs-137 released from WOCD, Sorbed, Decayed. and lost over W
Curies - no storm
800
700
600
500
400
300
200
100
0
0
5000
10000
15000
20000
25000
June 1,1943 - January 1,1949 - April 30,1991 - April 30, 2001 (days)



Cumulative Amounts Cs-137 released from WOCD, Sorbed, Decayed. and lost over W
Curies - system wide storm
800
700
600
500
400
300
200
100
0
0
5000
10000
15000
20000
25000
June 1,1943 - January 1,1949 - April 30,1991 - April 30, 2001 (days)



WATTS BAR RESERVOIR CLINCH RIVER MI. 4.2 SEDIMENT RANGE #31
——OCT 1946 ----JUNE 1991



WATTS BAR RESERVOIR CLINCH RIVER MI. 1.3 SEDIMENT RANGE #30
——OCT 1946 ----JUNE 1991